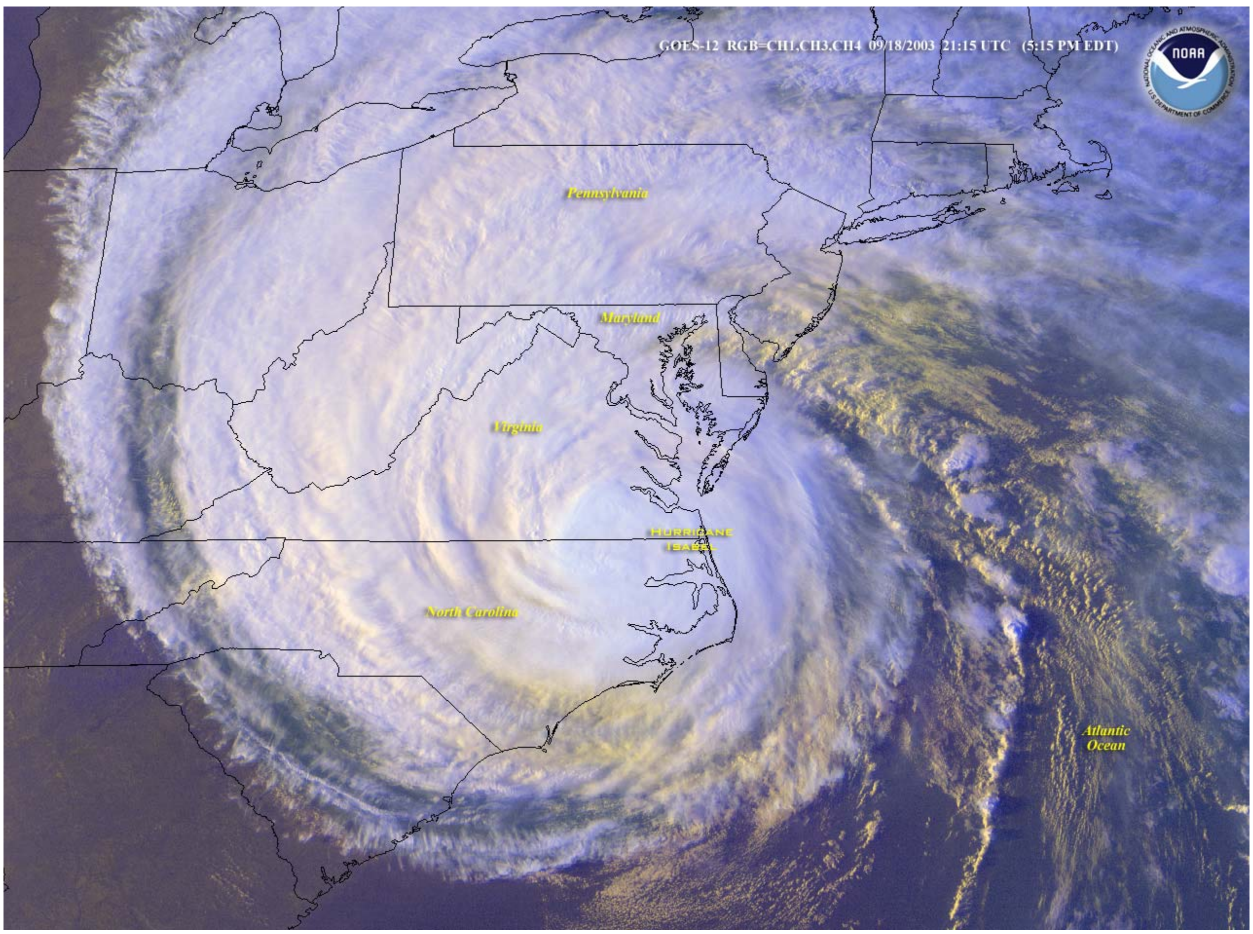
Hurricane Isabel Assessment

Review of Hurricane Evacuation Study Products and Other Aspects of the National Hurricane Mitigation and Preparedness Program (NHMPP) in the Context of the Hurricane Isabel Response



March 2005

U.S. Army Corps of Engineers

FEMA

HURRICANE ISABEL ASSESSMENT

Review of Hurricane Evacuation Study Products and Other Aspects of the National Hurricane Mitigation and Preparedness Program (NHMPP) in the Context of the Hurricane Isabel Response

Prepared for

U.S. Army Corps of Engineers
Philadelphia and Wilmington Districts
And
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Region III and IV

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LIST OF ACRONYMS AND ABBREVIATIONS

ARC	American Red Cross
ASOS	Automated Surface Observing System (NWS & FAA)
CBBT	Chesapeake Bay Bridge Tunnel (across mouth of Chesapeake Bay)
CD	Compact Disk
CHART	Coordinated Highways Action Response Team (in Maryland)
DAE	Disaster Assistance Employee (FEMA)
Delmarva	DELaware, MARyland and VirginiA (peninsula or region)
DEM	Department / Division of Emergency Management (VDEM)
DFO	Disaster Field Office
DHS	Department of Homeland Security
DHR	Department of Human Resources
DOT	Department of Transportation (NC DOT)
EAS	Emergency Alert System
ELT	Evacuation Liaison Team
EM	Emergency Managment
EMA	Emergency Management Agency/ies
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ESF	Emergency Support Function
EST	Emergency Support Team
ETIS	Evacuation Traffic Information System
FCO	Federal Coordinating Officer
FEMA	Federal Emergency Management Agency
FHwA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FSKB	Francis Scott Key Bridge (over Baltimore Harbor)
GIS	Geographic Information Systems
GOES	Geostationary Operational Environmental Satellite
HAR	Highway Advisory Radio
HAZUS	Hazards United States (Software Program)
HES	Hurricane Evacuation Study
HESE	Hurricane Evacuation Shelter Evaluation
HLT	Hurricane Liaison Team
HURREVAC	HURRicane EVACuation Tracking and Analysis Software
ICCOH	Intergovernmental Coordination Committee on Hurricanes
IFLOWS	Integrated Flood Observing and Warning System
ITS	Intelligent Transportation Systems
LIDAR	Light Detection And Ranging
MD	State of Maryland
MEMA	Maryland Emergency Management Agency
MEOW	Maximum Envelope of Water (from SLOSH Program)
MH	Mobile / Manufactured Home
MLLW	Mean Low Low Water
MOM	Maximum of Maximum (from SLOSH Program)
NAD	North American Datum

NAVD	North American Vertical Datum
NAWAS	National Warning System
NC	State of North Carolina
NCEM	North Carolina Emergency Management
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NHC	National Hurricane Center
NHMPP	National Hurricane Mitigation and Preparedness Program
NOAA	National Oceanographic and Atmospheric Administration
NOS	National Oceanographic Service
NWS	National Weather Service
PBS & J	Post, Buckley, Schuh and Jernigan
PIO	Public Information Officer
PSN	People with Special Needs
RAWS	Remote Automated Weather Stations
RMW	Radius of Maximum Winds
ROC	Regional Operation Center
ROLR	Refuge of Last Resort
SHP	State Highway Patrol (NC SHP, VA SHP, MD SHP)
SCO	State Coordinating Officer
SLOSH	Sea, Lake and Overland Surges from Hurricanes
SO	Sheriff's Office
SMA	Standard Metropolitan Area (from U.S. Census)
TDR	Technical Data Report (part of Hurricane Evacuation Study)
TMC	Traffic Management Center
TPC	Tropical Prediction Center
TWC	The Weather Channel
USACE	U.S. Army Corps of Engineers
UTC	Coordinated Universal Time (Greenwich Mean Time)
VA	State of Virginia
VDOT	Virginia Department of Transportation
WFO	Weather Forecast Office

EXECUTIVE SUMMARY

At about 1:00 PM, Thursday September 18th, 2003, Hurricane Isabel came ashore near Drum Inlet on North Carolina's Outer Banks as a category 2 hurricane with sustained winds of 100 miles per hour. On its long trek across the Atlantic Ocean, the tropical cyclone attained category 5 status and then fortunately lost much of its intensity before making landfall. Hurricane Isabel thereby spared the states and communities in its path the worst it could offer.

Nonetheless for North Carolina, Virginia and Maryland, Hurricane Isabel was a major storm with surprising impacts on the populations and property within those states. Isabel was directly responsible for 16 deaths: 10 in Virginia and 1 each in North Carolina, Maryland, New Jersey, New York, Rhode Island, and Florida. The hurricane was also indirectly responsible for 38 deaths: 26 in Virginia, 6 in Maryland, 2 in North Carolina and Pennsylvania, and 1 each in New Jersey and the District of Columbia. The storm caused widespread wind and storm surge damage in coastal eastern North Carolina and southeastern Virginia. Storm surge damage also occurred along Chesapeake Bay and the associated river estuaries, while wind damage occurred over portions of the remaining area from southern Virginia northward to New York. The current nationwide estimate for insured property damage is $1.685 billion, or

- $925 million in Virginia;
- $410 million in Maryland;
- $170 million in North Carolina;
- $80 million in Pennsylvania;
- $45 million in New York;
- $25 million in New Jersey,
- $20 million in Delaware, and
- $10 million in West Virginia.

The total damage for Isabel is estimated to be about twice that of the insured damage, or $3.37 billion.

Despite these casualty and damage figures, many local governments reported that relatively few people actually evacuated, or if they did so it was very late in the event timeline, during the pre-landfall hazards time. Consequently, only isolated incidents of road blockages or traffic congestion were reported by state and local officials during the evacuation and no communities were aware of instances where residents could not leave vulnerable areas or were stranded on the roadways in the middle of the storm.

Prior to Hurricane Isabel, the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (USACE) had completed comprehensive hurricane evacuation studies (HES) for the predominantly coastal communities in all three states. The previous studies for Virginia and Maryland are in need of updating because they were completed in 1992 and 1990 respectively which reduces their utility for hurricane protective action decision making, as well as for implementing preparedness and response operations. Nonetheless, several new SLOSH (Sea Lake and Overland Surges from Hurricanes) basins were recently constructed and models run for the Ocean City and Norfolk areas. Additionally, models were re-run for the Delaware Bay and Chesapeake Bay basins. New or revised studies are underway for the Maryland Western Shore, Virginia, and the Delmarva Peninsula. Given the advent of these new studies in the Isabel landfall region, a post-storm assessment provides an opportunity to gather data which will enhance study work products. Among the data objectives for this post-storm study are:

- Establishing whether federal, state or local officials used the products developed from these studies;
- Determining the accuracy and reliability of study data regarding storm hazards, behavioral characteristics of the threatened population, shelter information, clearance times and other evacuation decision making variables;
- Ascertaining which products were most and least useful;
- Proposing improvements to current study methodologies and work products; and
- Assessing the ability of the entire National Hurricane Mitigation and Preparedness Program (NHMPP) to adequately address the needs of federal, state and local officials with respect to hurricane preparedness, response and mitigation issues.

Study teams comprised of representatives from FEMA, USACE, State Emergency Management Offices and the contractor - Post, Buckley, Schuh and Jernigan, Inc. (PBS & J) met with local and state officials in North Carolina, Virginia and Maryland to discuss the above issues, especially in the context of the experiences gained during Hurricane Isabel. In these discussions the following generalizations became apparent:

- ► The data in the Hurricane Evacuation Studies for Virginia and Maryland are somewhat dated and should be updated as soon as possible;
- ► Most state and local government officials enjoyed an excellent working relationship with their local National Weather Service (NWS) Offices;
- ► Most local governments liked the five-day forecasts provided as part of the National Hurricane Center's (NHC) advisory packages;
- ► HURREVAC was almost universally used by state and local officials and was praised for its utility and ease of use;
- ► There is some lack of understanding regarding which tools provided under the NHMPP are appropriate for protective action decision-making;
- ► There is a widespread need for an intensive hurricane curriculum oriented more towards evacuation decision making and response operations and a more extensive means of delivering that training to local government officials;
- ► Very few of the surveyed local officials knew of or used the Hurricane Liaison Team (HLT);
- ► All three states apparently experienced relatively low participation rates during their evacuations and consequently experienced only a few isolated problems with traffic congestion;
- ► Many government officials and the public were surprised by the severity of the impacts caused by Isabel as a tropical storm;
- ► Despite fewer people evacuating than expected during Hurricane Isabel, there were nonetheless pervasive issues with sheltering operations including: staffing shortfalls; the need for coordinated plans at state and federal level; lack of security; isolated instances of overcrowding; accommodating foreign speaking populations; the presence of homeless people; and other resource limitations; and
- ► Communicating with ethnic populations was a significant problem for state and local governments, which has considerable implications for evacuation, sheltering and recovery operations.

Some of the recommendations below are outside the scope of those normally provided in post-storm analyses. In looking over the results from the communities surveyed for this effort, it became apparent that many of the problems that were evident during Hurricane Isabel would not be adequately addressed by changes to NHMPP products or processes alone. Additionally, many of the recommendations contained in this document were based on requests from the state and local governments interviewed for this effort. Therefore, the recommendations in this report reflect a decision by most of the post-storm study team members who collaborated on compiling this document to address the preparedness and response issues observed during Hurricane Isabel in a comprehensive manner and propose corrective actions that apply to fundamental programmatic and policy issues, as well as to the perfunctory NHMPP product improvement measures.

Based on the general observations above, and the wealth of additional information collected from state and local officials in all three surveyed states, the recommendations below are provided as a specific means to improving the products and activities of the NHMPP for future tropical cyclone events:

1. Review, update and improve the resolution of the current SLOSH study for the Chesapeake Bay. (This work was completed by the end of 2004.)
2. Incorporate hypothetical hurricanes, similar to Isabel, into the Chesapeake Bay SLOSH model to determine the potential storm tide impacts, especially for the northern end of the basin. (This work was underway as of early 2005 with an anticipated completion timeframe of late summer 2005).
3. Generate new SLOSH Maximum Envelopes of Water (MEOWs) and Maximum of the Maximums (MOMs) for use in determining changes to existing hurricane evacuation zones. (Revised mapping based on new MEOWs and MOMs is included in the current HES work plans.)
4. Develop an intensive training program for state and local emergency management staff regarding the appropriate use of Storm Tide Atlases, the SLOSH Display Program and evacuation zone maps in evacuation decision making and response operations.

5. Develop a comprehensive campaign to impress on the public and local decision-makers alike that the dangers associated with tropical storms and lesser category hurricanes warrant protective actions.
6. Review and/or communicate the real missions of the HLT and develop the procedures and technical capabilities to support those roles.
7. Create a cadre of NHMPP representatives (USACE, FEMA and State Program Managers) available for deployment to state and local government Emergency Operations Centers (EOC) to act as on-site technical advisors for hurricane evacuation and response operations.
8. Develop a generic version of the Hurricane Risk Profile in HURREVAC that is applicable to all state and local governments to increase consistency in decision making during actual tropical cyclone events.
9. Develop a more streamlined format for conducting the video conferences between the HLT, the States and the Emergency Support Team (EST).
10. Expedite completing the HESs for Virginia, Maryland and the Delmarva Region as soon as possible.
11. Expand the study area for the Virginia HES Restudy to include communities further inland along the tributaries of Chesapeake Bay: the James, York, Rappahannock and Potomac Rivers.
12. Develop a training program as part of the HES study process that continually educates state and local officials regarding the use of study products and tools.
13. In concert with the current NFIP Map Modernization Program and other improved mapping efforts, improve the base mapping used in the development of SLOSH model basins and storm tide mapping.
14. For communities and regions with 18-hour or greater clearance times, provide decision making criteria in future transportation analyses that state and local governments can use to develop and implement evacuation shutdown procedures.
15. Develop a more rigorous and organized training program for HURREVAC to ensure that hands on and operational use classes are made available to key disaster-related staff in all hurricane-vulnerable communities on at least an annual basis.

16. Develop a systematic approach to issuing HURREVAC program updates on the same dates every year, or create the capability to automatically feed version upgrades during routine data downloads.
17. Provide local emergency management with the ability to readily access sea buoy, coastal tide gauge and IFLOWS rain and river gauge data, i.e. incorporating a function that automatically collects and displays that data in HURREVAC. Despite close coordination between local emergency management offices and the NWS office, high water levels in the mid and upper reaches of Chesapeake Bay caught waterside populations by surprise. Several emergency managers indicated that ready access to open water buoy and tidal gauge information might be of value in alerting them to rising water.
18. Develop a formal training program for the Evacuation Traffic Information System (ETIS) that details the operational uses of its functions during evacuations, and ensure that the courses are routinely delivered to federal, state and local officials before each hurricane season.
19. Expand and re-vamp the entire curriculum for the NHMPP to include more in-depth training on planning, preparedness, mitigation, and response operations (pre- and post- landfall) for hurricanes.
20. Formalize the delivery means for field-based hurricane courses, especially to local officials, to ensure better training coverage and frequency.
21. Develop and distribute more training-aids to facilitate hurricane response operations and activities at the state and local level.
22. Increase the national emphasis to integrate emergency management requirements into the Intelligent Transportation System (ITS) architecture at the federal and state level.
23. Expedite the development of travel demand modeling capabilities in ETIS for Maryland and Virginia.
24. Expedite the addition of travel demand modeling capabilities for all remaining coastal counties included in the North Carolina HES.
25. Advance the development of an automatic traffic counter data assimilation function into ETIS for all states that have real time capabilities.
26. Develop a new component in ETIS that will allow evacuation planners at the state level to investigate the traffic impacts of various evacuation strategies or alternatives.

27. Advocate and encourage in all hurricane-prone states the concept of sheltering evacuees locally as a better protective action for hurricanes than traditional evacuation strategies. Although Hurricane Isabel did not generally expose a serious shortage of public shelter capacity in any of the communities surveyed during this effort, several emergency managers expressed concern about anticipated shelter space deficits in other hurricane scenarios.
28. Provide state and local governments with the guidance needed to become self-sufficient in staffing their shelters during hurricanes.
29. Encourage an increase in the inventory of ARC 4496 compliant shelters at the local and regional level for all states participating in the NHMPP. Hurricane Isabel did not generally tax the structural capabilities of most buildings used as public shelters, nonetheless a considerable number of emergency managers expressed a lack of confidence in the performance of their shelter facilities in hurricane force conditions.
30. Develop comprehensive guidance regarding the policies, operational requirements and resources needed to implement an effective populations with special needs (PSN) sheltering program at the state and local level. Although no pervasive problems surfaced during Hurricane Isabel, a significant number of emergency managers specifically requested direction and technical assistance for establishing programs to better protect their special needs populations during disasters.
31. Develop a comprehensive training and education program for communities and media organizations alike regarding better methods for integrating their public information operations during hurricanes and other disasters. The experiences of surveyed state and local governments did not expose any overwhelming issues with respect to public information during Hurricane Isabel; nonetheless many emergency management directors expressed concern about the success of their future operations under different hurricane circumstances.
32. Develop a one-stop comprehensive information webpage, possibly at the HLT site, that assists state and local government representatives in readily gathering all information that specifically relates to hurricane hazards or the overall event. No emergency manager in a surveyed community expressly indicated that obtaining salient information about Hurricane Isabel from the Internet was difficult, instead this recommendation stems from other indications during the interviews that not all information was readily accessible or even used to full advantage.

33. Provide assistance to state and local governments in preparing hurricane-specific information in various media to effectively communicate with ethnic populations.

Chapter 1

Introduction and Recommendations Summary

A thorough survey of state and local government officials in the three states of North Carolina, Virginia and Maryland were conducted to collect decision making and operational response data related to evacuations and other protective actions during Hurricane Isabel. These surveyed government representatives provided information that should be useful in improving the products and processes currently used by the agencies and jurisdictions participating in the National Hurricane Mitigation and Preparedness Program (NHMPP). State and local government officials were asked questions about their actions, experiences and observations during the hours leading up to the landfall of Hurricane Isabel and the first few days immediately thereafter.

The interviews of state and local government officials were conducted over the course of two months, March and April 2004, and usually occurred within the communities providing the information. In North Carolina, Virginia and Maryland the following communities participated in the surveys:

North Carolina

- Beaufort County;
- Bertie County;
- Brunswick County;
- Camden and Pasquotank Counties;
- Carteret County;
- Chowan County;
- Craven County;
- Currituck County;
- Dare County;
- Hyde County;
- Jones County;
- Martin County;
- New Hanover County;
- Onslow County;
- Pamlico County;
- Pender County;
- Perquimans County;
- Tyrrell County; and
- Washington County.

Virginia

- Accomack County;
- City of Chesapeake;
- Town of Chincoteague;
- Gloucester County;
- City of Hampton;
- Isle of Wight County;
- Lancaster County;
- Mathews County;
- City of Newport News;
- Northumberland County;
- City of Poquoson;
- City of Portsmouth;
- Richmond County;
- City of Suffolk;
- City of Virginia Beach;
- Westmoreland County;
- City of Williamsburg; and
- York County.

Maryland

- Anne Arundel County;
- Baltimore County;
- City of Baltimore;
- Calvert County;
- Charles County;
- Harford County;
- Howard County;
- Prince George's County; and
- St. Mary's County.

Additionally, each state Emergency Management Agency (EMA) and other associated organizations with responsibilities in each of the state Emergency Operations Centers (EOC) were interviewed. Local media was also asked to provide input to this post-storm assessment regarding how they coordinated their operations with the activities of local government officials and EOCs. Among the media organizations that provided information were: WNIS News Radio in Norfolk, VA; WTVR, CBS-TV Channel 6, WWBT NBC-TV Channel 12 and WRVA News Radio in Richmond, VA; and WTOP News Radio in Washington, D.C. Other relevant information regarding the Hurricane Isabel experience was obtained from individual counties, including some not listed above, by U.S. Army Corps of Engineer Hurricane Evacuation Study managers through routine visits and communications.

This report also includes information from communities not specifically interviewed by the survey teams for this particular effort. The information for these local governments was obtained through presentation materials provided at conferences, or collected through other means not necessarily associated with this endeavor. Among these communities are the City of Norfolk in Virginia, as well as Caroline, Cecil, Dorchester, Kent, Queen Anne's, and Talbot Counties in Maryland.

The topics of the survey responses generally fall into the following categories, which also establish the format for presenting the data contained in this report: hazards and vulnerability data; protective action decision making; hurricane evacuation study and NHMPP products; behavioral analysis; transportation and evacuation; sheltering; and public information and emergency communications.

Based on the observations, suggestions and requests collected from state and local officials during the interviews, below in Table 1-1 are recommendations for improving the products, processes and programmatic details of NHMPP. Additionally, each recommendation in the table is related to the appropriate goal in the NHMPP Strategic Plan, as well as the NEMA/State Goals, Objectives and Priorities for the Program.

Table 1-1. Recommendations Summary

Recommendation Chapter and Number	Recommendation Text	NHMPP Strategic Plan [1]	NEMA / State NHMPP Goals, Objectives and Priorities [2]
3-1	**Review, update and improve the resolution of the current SLOSH study for the Chesapeake Bay.**	3.3	Goal 3
3-2	**Incorporate hypothetical hurricanes, similar to Isabel, into the Chesapeake Bay SLOSH model to determine the potential storm tide impacts, especially for the northern end of the basin.**	3.3	Goal 3
3-3	**Generate New SLOSH Maximum Envelopes of Water (MEOWs) and Maximum of the Maximums (MOMs) for use in determining changes to existing hurricane evacuation zones**.	3.3	Goal 3
4-1	**Develop an intensive training program for state and local emergency management staff regarding the appropriate use of Storm Tide Atlases, the SLOSH Display Program and evacuation zone maps in evacuation decision making and response operations.**	4.1	Objective 2.4
4-2	**Develop a comprehensive campaign to impress on the public and local decision-makers alike that the dangers associated with tropical storms and lesser category hurricanes warrant protective actions.**	2.2	Objective 2.4
4-3	**Review and/or communicate the real missions of the HLT and develop the procedures and technical capabilities to support those roles.**	2.3.2	Goal 2
4-4	**Create a cadre of NHMPP representatives (USACE, FEMA and State Program Managers) available for deployment to state and local government Emergency Operations Centers (EOC) to act as on-site technical advisors for hurricane evacuation and response operations.**	2.3.2	Goal 2
4-5	**Develop a generic version of the Hurricane Risk Profile in HURREVAC that is applicable to all state and local governments to increase consistency in decision making during actual tropical cyclone events.**	2.3	Goal 2
4-6	**Develop a more streamlined format for conducting the video conferences between the HLT, the states and the EST.**	2.3.2	Goal 2
5-1	**Expedite completing the HESs for Virginia, Maryland and the Delmarva Region as soon as possible**.	2.1.5	Goal 3
5-2	**Expand the study area for the Virginia HES Restudy to include communities further inland along the tributaries of Chesapeake Bay: the James, York, Rappahannock and Potomac Rivers.**	2.1.5	Goal 3

Recommendation Chapter and Number	Recommendation Text	NHMPP Strategic Plan [1]	NEMA / State NHMPP Goals, Objectives and Priorities [2]
5-3	**Develop a training program as part of the HES study process that continually educates state and local officials regarding the use of study products and tools.**	4.1	Objective 2.4
5-4	**In concert with the current NFIP Map Modernization Program and other improved mapping efforts, improve the base mapping used in the development of SLOSH model basins and storm tide mapping.**	3.3	Objective 3.6
5-5	**For communities and regions with 18-hour or greater clearance times, provide decision making criteria in future transportation analyses that state and local governments can use to develop and implement evacuation shutdown procedures.**	2.4.6 & 2.4.7	Objective 2.7
5-6	**Develop a more rigorous and organized training program for HURREVAC to ensure that hands-on and operational use classes are made available to key disaster-related staff in all hurricane-vulnerable communities on at least an annual basis.**	4.1	Goal 2
5-7	**Develop a systematic approach to issuing HURREVAC program updates on the same dates every year, or create the capability to automatically feed version upgrades during routine data downloads.**	2.3.1	Goal 2
5-8	**Provide local emergency management with the ability to readily access sea buoy, coastal tide gauge and IFLOWS rain and river gauge data, i.e. incorporating a function that automatically collects and displays that data in HURREVAC.**	2.3.1& 2.4.2	Objective 3.1 & 3.5
5-9	**Develop a formal training program for ETIS that details the operational uses of its functions during evacuations, and ensure that the courses are routinely delivered to federal, state and local officials before each hurricane season.**	4.1 & 4.1.6	Objective 2.4
5-10	**Expand and re-vamp the entire curriculum for the National Hurricane Mitigation and Preparedness Program to include more in-depth training on planning, preparedness, mitigation, and response operations (pre- and post- landfall) for hurricanes.**	4.1	Objective 2.4.1
5-11	**Formalize the delivery means for field-based hurricane courses, especially to local officials, to ensure better training coverage and frequency.**	4.1.2 & 4.2.2	Objective 2.4
5-12	**Develop and distribute more training-aids to facilitate hurricane response operations and activities at the state and local level.**	4.1	Goal 2
7-1	**Increase the national emphasis to integrate emergency management requirements into the ITS architecture at the federal and state level.**	1.1	Objective. 2.2

Recommendation Chapter and Number	Recommendation Text	NHMPP Strategic Plan [1]	NEMA / State NHMPP Goals, Objectives and Priorities [2]
7-2	**Expedite the development of travel demand modeling capabilities in ETIS for Maryland and Virginia.**	2.4.10	Objective. 2.3
7-3	**Expedite the addition of travel demand modeling capabilities for all remaining coastal counties included in the North Carolina HES.**	2.3.4	Objective. 2.3
7-4	**Advance the development of an automatic traffic counter data assimilation function into ETIS for all states that have real time capabilities.**	2.1.1	Goal 2 & Objective 2.3
7-5	**Develop a new component in ETIS that will allow evacuation planners at the state level to investigate the traffic impacts of various evacuation strategies or alternatives.**	2.1.1	Goal 2 & Objective 2.3
8-1	**Advocate and encourage in all hurricane prone states the concept of sheltering evacuees locally as a better protective action for hurricanes than traditional evacuation strategies.**	1.1	Goal 4
8-2	**Provide state and local governments with the guidance needed to become self-sufficient in staffing their shelters during hurricanes.**	1.1	Goal 4 & Objective 4.7
8-3	**Encourage an increase in the inventory of ARC 4496 compliant shelters at the local and regional level for all states participating in the National Hurricane Mitigation and Preparedness Program.**	2.1.6	Objective 4.4
8-4	**Develop comprehensive guidance regarding the policies, operational requirements and resources needed to implement an effective populations with special needs (PSN) sheltering program at the state and local level.**	1.1	Objective 2.11
9-1	**Develop a comprehensive training and education program for communities and media organizations alike regarding better methods for integrating their public information operations during hurricanes and other disasters.**	2.5 & 5.1	Objective 2.4.2 & 5.7
9-2	**Develop a one-stop comprehensive information webpage, possibly at the HLT site, that assists state and local government representatives in readily gathering all information that specifically relates to hurricane hazards or the overall event.**	1.3.7	Goal 2
9-3	**Provide assistance to state and local governments in preparing hurricane-specific information in various media to effectively communicate with ethnic populations.**	2.2.3	Goal 5

1 See Appendix D
2 See Appendix E

Chapter 2
Hurricane Isabel Event Milestones

On September 1, 2003 a tropical wave exited the coast of Africa and began its long trip across the Atlantic. By September 6th, the wave had become a tropical depression and on September 7, the wave reached hurricane status receiving the name Isabel. Four days later Hurricane Isabel had intensified into a category 5 hurricane with sustained hurricane winds estimated at 145 knots, or 166 miles per hour. Fortunately, before it made landfall, Hurricane Isabel encountered an area of vertical wind shear over the Atlantic Ocean which reduced its strength to a category 2 storm. Thus, the Middle Atlantic coast of the United States was spared the impacts of a major hurricane.

In response to the approaching storm, numerous agencies and organizations at the federal, state and local level began in earnest to prepare for the eventuality of implementing protective actions and other response activities. The National Hurricane Center (NHC) and the Federal Emergency Management Agency (FEMA) activated the Hurricane Liaison Team (HLT) and Evacuation Liaison Team (ELT) to provide technical assistance to state and local governments in their decision making. FEMA also implemented the Federal Response Plan to begin stationing the resources required to assist state and local governments with evacuation and sheltering operations, as well as related response and recovery activities.

Hurricane Isabel remained a category 2 hurricane until it made landfall near Drum Inlet on the Outer Banks of North Carolina at 1:00 PM Eastern Daylight Time, September 18, 2003. At landfall, Isabel had sustained winds of 100 miles per hour and its hurricane-force windfield was estimated by the NHC to extend along the coast from the North Carolina/Virginia Border to Camp Lejeune in Onslow County and as far inland as the communities of Windsor, Greenville and Kinston in North Carolina. At that time, all of Pamlico and Albemarle Sounds were subjected to hurricane-force winds, as well as punishing storm tides and waves. The NHC advisory also indicated the tropical storm-force wind ellipse spanned the coast from Myrtle Beach, South Carolina, to Atlantic City in New Jersey. The eye traversed North Carolina, passing near Pamlico Beach at 3:00 PM, moving to the vicinity of Aulander by 5:00 in the afternoon and exiting into Virginia close to I-95 in Pleasant Hill at about 7:00 that evening.

Isabel was still a category 1 hurricane with sustained winds of 80 miles per hour when its eye crossed the state line into Virginia. At that location, the NHC advisory estimated that the hurricane-force windfield encompassed the entire Hampton Roads urbanized area including all of Virginia Beach. As testimony to the vast size of this storm the tropical storm wind ellipse extended from Myrtle Beach, South Carolina, to Asbury Park in New Jersey and extended inland from Hazelton, Pennsylvania, in the north to Bluefield, West Virginia, in the west and Charlotte, North Carolina, in the southwest.

At 9:00 PM on September 18th, the NHC in Intermediate Advisory 51 B dropped the intensity of Isabel to below hurricane strength with sustained winds of 70 mph. At this point the right front quadrant of the 58 mile per hour sustained wind ellipse engulfed most of Chesapeake Bay including the mouth. For approximately 8 hours, onshore winds of gale force or greater pushed the storm tide directly into Chesapeake Bay and prevented its escape. The winds continued as the center of circulation progressed to the northwest across Virginia, retaining the storm tide in Chesapeake Bay and furthermore pushing it up far into its northern reaches. For Washington, D.C., as well as Baltimore and Annapolis in Maryland, Hurricane Isabel surpassed the previous record surge levels established in the 1933 Hurricane.

Friday the 19th of September, 2003, saw Tropical Storm Isabel's center of circulation cross into West Virginia and then into Pennsylvania. Even with the center just east of Pittsburg, the tropical storm wind ellipse from the 8:00 AM NHC intermediate advisory included most of Pennsylvania, Maryland, Delaware, and New Jersey and extended well into Virginia, West Virginia and New York. At the 11:00 AM advisory on that same day, with the storm's center located near Ashtabula, Ohio, the NHC indicated that Isabel had become an extra-tropical storm and they discontinued any further advisories.

Table 2-1 below establishes a general timeline for Hurricane Isabel regarding the operational decisions of the surveyed communities and state agencies relative to storm and event data that may have had some influence on their actions. The activation or start times provided in the timeline were extracted from the Post-Storm surveys conducted in March and April, 2004.

Figure 2-2 is a HURREVAC map of the track of Hurricane Isabel from September 10th to its dissipation as an extra-tropical storm on September 19th, 2003. The locations provided on the HURREVAC map reflect the initial storm positions provided by the NHC in each of their advisory packages.

Figure 2-1. Survey Meeting in Chincoteague, Virginia

Table 2-1. Hurricane Isabel Event Timeline

Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	VA	MD[10]	NC	VA	MD[11]
Sun, Sept 6 0900 Hours	Tropical depression becomes tropical storm and is named Isabel						
Sun, Sept 7 1100 Hours	Isabel becomes a hurricane						
Thurs, Sept 9 1700 Hours	• Isabel becomes a cat 5 hurricane • Tropical storm wind field > 1,600 miles away along actual track						
Thurs, Sept 12	Cat 5			Prince George's [7]			
Fri, Sept 12	Cat 5			Howard [7]			
Sun, Sept 14 1100 Hours	• Isabel down to Cat 4 intensity • Tropical storm wind field > 850 miles away along actual track						
Sun, Sept 14 1700 Hours	• NC in 72-hour avg. error cone • Tropical storm winds forecast for NC in 72 hours						
Mon, Sept. 15							
0100 Hours	Cat 4						
0200 Hours	Cat 4						
0300 Hours	Cat 4						
0400 Hours	Cat 4						
0500 Hours	Advisory 37; Cat 4						
0600 Hours	Cat 4						
0700 Hours	Cat 4			St. Mary's			
0800 Hours	Cat 4	**Currituck**; Dare	VA EMA [6]	MD EMA [6 7]			
0900 Hours	Cat 4						
1000 Hours	Cat 4						
1100 Hours	Advisory 38; Cat 4						
1200 Hours	Cat 4		Hampton				
1300 Hours	Cat 4						
1400 Hours	Cat 4						
1500 Hours	Cat 4						
1600 Hours	Cat 4						

Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	VA	MD[10]	NC	VA	MD[11]
Mon, Sept. 15 (Continued)							
1700 Hours	• Advisory 39; Cat 4 • Isabel a Cat 3 storm • Tropical storm winds forecast to arrive in NC in 56 hours, VA in 61 hours						
1800 Hours	Cat 3						
1900 Hours	Cat 3						
2000 Hours	Cat 3						
2100 Hours	Cat 3						
2200 Hours	Cat 3						
2300 Hours	Advisory 40; Cat 3						
2400 Hours	Cat 3						
Tues, Sept. 16							
0100 Hours	Cat 3						
0200 Hours	Cat 3						
0300 Hours	Cat 3						
0400 Hours	Cat 3						
0500 Hours	Advisory 41; Cat 3						
0600 Hours	Cat 3	Carteret					
0700 Hours	Cat 3			Calvert	Carteret		
0800 Hours	Cat 3	Pamlico	Mathews [5]; Newport News; Norfolk; **VA EMA** [6]		Craven [6]		
0900 Hours	Cat 3		Lancaster				
1000 Hours	Cat 3						
1100 Hours	Advisory 42; Cat 3 • Hurricane Watch from Edisto Beach, SC to Chincoteague, VA • Isabel a Cat 2 storm • Tropical storm winds forecast to arrive in NC in 38 hours, VA in 43 hours						

Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	VA	MD[10]	NC	VA	MD[11]
Tues, Sept. 16 (Continued)							
1200 Hours	Cat 2	Hyde	**Northumber-land**; **Richmond**; **Westmore-land**	**Anne Arundel** [7]	**Currituck** (Outer Banks); Hyde		
1300 Hours	Cat 2		York				
1400 Hours	Advisory 42A; Cat 2						
1500 Hours	Cat 2				Camden & Pasquotank		
1600 Hours	Cat 2	Beaufort					
1700 Hours	Advisory 43; Cat 2	Jones					
1800 Hours	Cat 2	**Onslow**					
1900 Hours	Cat 2						
2000 Hours	Advisory 43A; Cat 2						
2100 Hours	Cat 2						
2200 Hours	Cat 2						
2300 Hours	Advisory 44; Cat 2 • Hurricane Warning from Cape Fear, NC to NC/VA border • Tropical Storm winds forecast to arrive in NC in 24 hours, VA in 29 hours						
2400 Hour s	Cat 2						
Wed, Sept. 17							
0100 Hours	Cat 2						
0200 Hours	Advisory 44A; • Tropical Storm winds forecast at 24 hours from landfall in VA						
0300 Hours	Cat 2						
0400 Hours	Cat 2						
0500 Hours	Advisory 45; Cat 2 • Hurricane Warning extended from Cape Fear, NC to Chincoteague • MD remains in Hurricane Watch area	**Carteret**; **Dare**					
0600 Hours	Cat 2	Pender	Accomack	**Calvert**;			

Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	VA	MD[10]	NC	VA	MD[11]
Wed, Sept. 17 (Continued)							
0700 Hours	Cat 2			Baltimore Co.;	**Carteret**;		Baltimore Co. [5];
0900 Hours	Cat 2						
1000 Hours	Cat 2		Suffolk			Lancaster [9]; Mathews [9]; **Westmore-land**	
1100 Hours	Advisory 46; Cat 2 • Tropical Storm winds forecast at 12 hours from landfall in NC • VA Gov. releases evacuation order permission to counties • All MD coastal areas revert to Tropical Storm Warning area		**Norfolk**; VA Beach [4]			**Chesapeake**; Isle of Wight[9]; **Newport News** [8]; **Norfolk**; Northumber-land [8]; Poquoson[8] [9]; Richmond [9]; Suffolk [9]; **VA Beach**; York [9]	
1200 Hours	Cat 2	**Bertie** [4]; **New Hanover** [7]; **Perquimans**[4]; **NC EMA**	Chesapeake; Poquoson		Bertie [4]; **Dare**; Perquimans [4]; **Tyrell**	Accomack [9]; Chinco - teague [9]; **Hampton**	
1300 Hours	Cat 2						
1400 Hours	Advisory 46A; Cat 2	Brunswick [5]; **Camden & Pasquotank**			Brunswick [5]; **Camden & Pasquotank**		
1500 Hours	Cat 2	**Pamlico**					

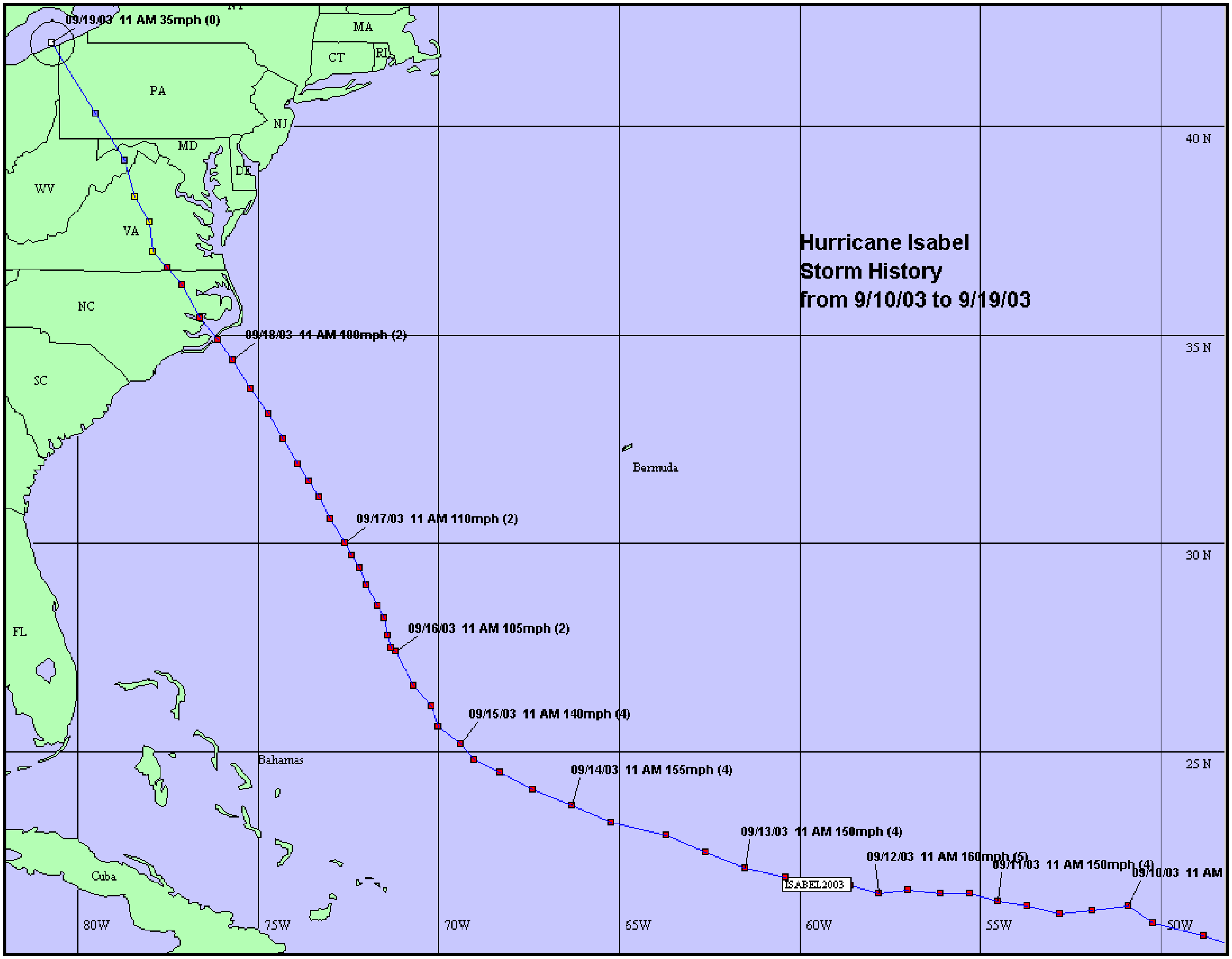
Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	VA	MD[10]	NC	VA	MD[11]
			Wed, Sept. 17 (Continued)				
1600 Hours	Cat 2	**Beaufort**	**Mathews**; **Newport News**; **Suffolk**		Beaufort		
1700 Hours	Advisory 47; Cat 2 • Tropical Storm winds forecast at 12 hours from landfall in VA	Martin; **Pender** [7]	Gloucester; **Hampton**; **Isle of Wight**		**Washington**		
1800 Hours	Cat 2	**Hyde**; **Martin** [7]	**Poquoson**			Gloucester [9]	
1900 Hours	Cat 2						
2000 Hours	Advisory 47A; Cat 2 • Landfall of tropical storm winds in NC • Tropical Storm winds forecast at 12 hours from landfall in MD						
2100 Hours	Cat 2						
2200 Hours	Cat 2						
2300 Hours	Advisory 48; Cat 2						
2400 Hours	Cat 2						
			Thurs, Sept. 18				
0100 Hours	Cat 2						
0200 Hours	Advisory 48A; Cat 2 • Landfall of tropical storm winds in VA (Virginia Beach)						
0300 Hours	Cat 2		**Chesapeake**				
0400 Hours	Cat 2						
0500 Hours	Advisory 49; Cat 2		**York**				
0600 Hours	Cat 2		**Accomack**; **Chincoteague**; **Gloucester**				

Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	**VA**	**MD[10]**	**NC**	**VA**	**MD[11]**
Thurs, Sept. 18 (Continued)							
0700 Hours	Tropical storm winds arrive at MD Eastern Shore			**St. Mary's**			St. Mary's [5]
0800 Hours	Advisory 49A; Cat 2 • Tropical storm winds arrive at MD Western Shore	**Washington**		**Baltimore City [7]**			
0900 Hours	Cat 2		**Lancaster**	**Harford [7]**			
1000 Hours	Cat 2						
1100 Hours	Advisory 50; Cat 2						
1200 Hours	Cat 2						**Calvert**
1300 Hours	Advisory 50A; Cat 2 • Landfall @ Drum Inlet, NC						
1400 Hours	Cat 2						
1500 Hours	Advisory 50B; Cat 2			**Charles**			
1600 Hours	Cat 2						
1700 Hours	Advisory 51 • Isabel becomes a Cat 1 storm						
1800 Hours	Cat 1						
1900 Hours	Advisory 51A; Cat 1 • Isabel's eye crosses into VA as a Cat 1						
2000 Hours	Cat 1						
2100 Hours	Advisory 51B; Tropical Storm • Isabel becomes a Tropical Storm						Charles
2200 Hours	Tropical Storm						**Charles**
2300 Hours	Advisory 52; Tropical Storm						
2400 Hours	Tropical Storm						
Fri, Sept. 19							
0100 Hours	Tropical Storm						
0200 Hours	Advisory 52A; Tropical Storm						
0300 Hours	Tropical Storm						
0400 Hours	Tropical Storm						
0500 Hours	Advisory 53; Tropical Storm						
0600 Hours	Tropical Storm						
0700 Hours	Tropical Storm						
0800 Hours	Advisory 53A; Tropical Storm						

Date / Time [1]	Situational Comments	EOC Activations [2]			Evacuation Orders [3]		
		NC	VA	MD[10]	NC	VA	MD[11]
Fri, Sept. 19 (Continued)							
0900 Hours	Tropical Storm						
1000 Hours	Tropical Storm						
1100 Hours	Advisory 54 • Isabel exits the U.S. below tropical storm strength						

1 All dates and times are in Eastern Daylight Time. Rows in gray (other than column headings) indicate approximate hours of darkness.
2 Non-bolded indicate partial EOC activation; **bolded** counties indicate **full** EOC activation.
3 Non-bolded indicate voluntary or recommended evacuations; **bolded** counties indicate **mandatory** evacuation.
4 For communities where specific times are not provided the assumed EOC activation time will coincide with the evacuation start time.
5 For communities where specific times are not provided the assumed evacuation time will coincide with the EOC activation time.
6 For communities where EOC activation and evacuation start dates do not coincide the assumed time for the evacuation will be at 8:00 AM of the stated day.
7 Did not order evacuations for their jurisdictions.
8 For communities where specific times are not provided the assumed evacuation time will coincide with the VA Governor's evacuation order authorization release.
9 Once the VA Governor provided evacuation order authorization at 11 AM on 9-17, all voluntary / recommended evacuations became mandatory.
10 The Eastern Shore counties in Maryland gradually activated their EOCs from Monday to Thursday as Hurricane Isabel approached.
11 Throughout Thursday night and the early morning hours of Friday Cecil, Kent, Caroline, Queen Anne's, Talbot and Dorchester Counties experienced last-minute, scattered, but widespread evacuations in response to unexpectedly high storm tides in the upper Chesapeake Bay.

Figure 2-2. HURREVAC Map of Hurricane Isabel Track



Chapter 3
Hazards and Vulnerability Data

In FEMA / USACE comprehensive hurricane evacuation studies (HES), the primary objective of the hazards analysis is to determine the probable worst-case effects for the various intensities of hurricanes that could strike the area. The Studies in these areas include the following:

- North Carolina HES – Update completed in 2002;
- Virginia HES – Original completed in 1992, update incomplete;
- Maryland HES (Eastern Shore counties) – Original completed in 1990, update (including the Western Shore counties that have not yet been studied) incomplete; and
- Delmarva Regional HES – Original incomplete.

The SLOSH basins in the Hurricane Isabel impact study survey area are:

- Wilmington NC/Myrtle Beach;
- Pamlico Sound;
- Norfolk; and
- Chesapeake Bay

A hazards analysis quantifies the expected hurricane-induced inundation area that would require evacuation of the population for various categories of hurricanes. The hazards analysis also assumes that mobile homes outside the surge inundation limits must also be evacuated in all categories of hurricanes. The National Weather Service's (NWS) SLOSH (Sea, Lake and Overland Surges from Hurricane) storm tide prediction model is the basis for the hazards analysis portion of the studies. The model output not only provides the data for the storm tide atlases, but is also used as the basis for developing the evacuation zones used in the HES and other hurricane preparedness materials.

The intent of this post-Isabel study hazards analysis is, through discussions with state and local emergency management and other public safety officials, to establish:

- What technical data and mapping was used to decide what areas to evacuate; and
- Did the technical data used provide an accurate representation of the hazard area?

High water marks and coastal tide gauge readings throughout the impacted area have been collected and analyzed against the results of the SLOSH model for Hurricane Isabel run by the NHC. These data and this analysis will be used to document the full extent of the storm tide as well as assess the accuracy of each SLOSH model basin.

Storm Tide Inundation in Upper Chesapeake Bay Jurisdictions

Hurricane Isabel confronted communities on the Chesapeake Bay with a potentially serious situation with respect to protective actions and public safety. During its entire life cycle, Isabel was very well behaved in that there was little divergence between the NHC's forecast track and intensity and the actual path and strength of the storm. Nonetheless, many contributing factors combined after landfall to make this tropical cyclone particularly noteworthy with respect to protective action decision making.

By Tuesday, September 16, 2003 the entire Middle Atlantic coast faced the possibility of being hit by a strong category 2 hurricane. The forecast track was trained on the North Carolina Outer Banks, but the average eye error swath displayed by HURREVAC extended from New Jersey to Myrtle Beach, South Carolina. However, as evacuation decision-making time neared for Upper Chesapeake Bay emergency management officials, Hurricane Isabel advisories continued to maintain a very consistent track, one which sent the eye of the storm - and presumably its highest winds - well to the west of the Upper Bay. Track forecast errors for the 12, 24, 36, 48 and 72-hour forecasts were 6, 12, 6, 16 and 31 nautical miles respectively. The forecast track also maintained its consistency and accuracy following landfall. The experience of Talbot County, Maryland is a representative example of the problems for decision making in the communities of the upper Chesapeake Bay during Isabel. Table 3-1 on the next page provides detail on the timing of the storm relative to Talbot County, Maryland.

From Isabel advisory 42 (Tuesday, September 16, 11 AM) through advisory 45A (Wednesday, September 17, 8 AM) the Upper Chesapeake Bay counties (north of Smith Point, VA) were under a hurricane watch. As of advisory 46 the hurricane watch was changed to a Tropical Storm Warning for this area (See Figure 3-1 below). The TS warning continued until the last Isabel advisory on Friday morning.

With confidence in the NHC track advisories, there were very few evacuation orders or recommendations issued by Upper Chesapeake Bay jurisdictions. Isabel was seen as "missing" the area. Figure 3-2 shows the storm's actual track compared to the North-Northwest tracks modeled for the Chesapeake Bay Basin SLOSH Model.

Table 3-1. Talbot County, MD: Isabel Parameters - Advisories 42 Through 49

HURREVAC Evacuation Timing Data: Hurricane Isabel - Talbot County, MD							
Advisory	**Date**	**Day**	**Time**	**Time Until 34 Knot Wind Arrival**	**Time To Decide**	**Forecast Wind Speed Near Landfall**	**Advisory Watch or Warning Areas**
42	16-Sep	TUES	11:00 AM	52 HRS	47 HRS	110 MPH	HUR WATCH
42A	16-Sep	TUES	2:00 PM	49 HRS	44 HRS	110 MPH	HUR WATCH
43	16-Sep	TUES	5:00 PM	46 HRS	41 HRS	110 MPH	HUR WATCH
43A	16-Sep	TUES	8:00 PM	43 HRS	38 HRS	110 MPH	HUR WATCH
44	16-Sep	TUES	11:00 PM	38 HRS	31 HRS	110 MPH	HUR WATCH
44A	17-Sep	WED	2:00 AM	35 HRS	28 HRS	110 MPH	HUR WATCH
45	17-Sep	WED	5:00 AM	33 HRS	27 HRS	110 MPH	HUR WATCH
45A	17-Sep	WED	8:00 AM	30 HRS	24 HRS	110 MPH	HUR WATCH
46	17-Sep	WED	11:00 AM	28 HRS	21 HRS	110 MPH	TS WARNING
46A	17-Sep	WED	2:00 PM	25 HRS	18 HRS	110 MPH	TS WARNING
47	17-Sep	WED	5:00 PM	21 HRS	16 HRS	110 MPH	TS WARNING
47A	17-Sep	WED	8:00 PM	18 HRS	13 HRS	110 MPH	TS WARNING
48	17-Sep	WED	11:00 PM	14 HRS	7 HRS	105 MPH	TS WARNING
48A	18-Sep	THURS	2:00 AM	11 HRS	4 HRS	105 MPH	TS WARNING
49	18-Sep	THURS	5:00 AM	6 HRS	0 HRS	105 MPH	TS WARNING

Figure 3-1. HURREVAC Image Of Hurricane Isabel at Advisory 46

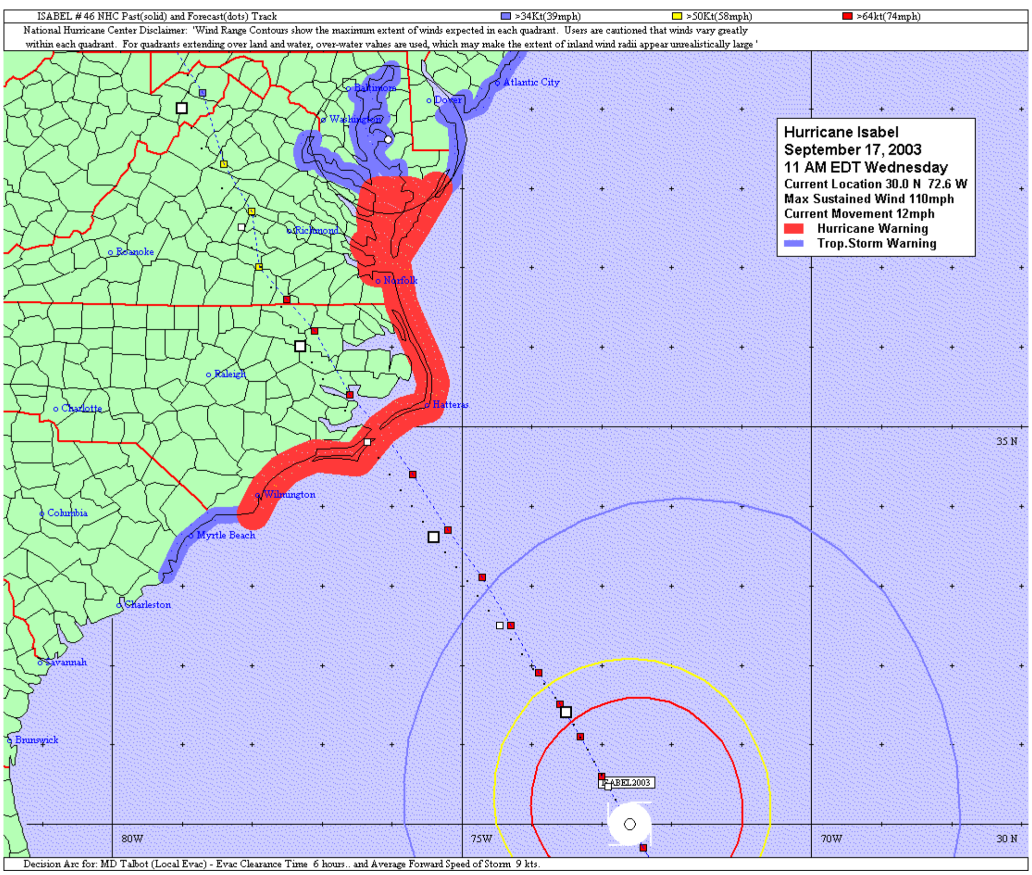
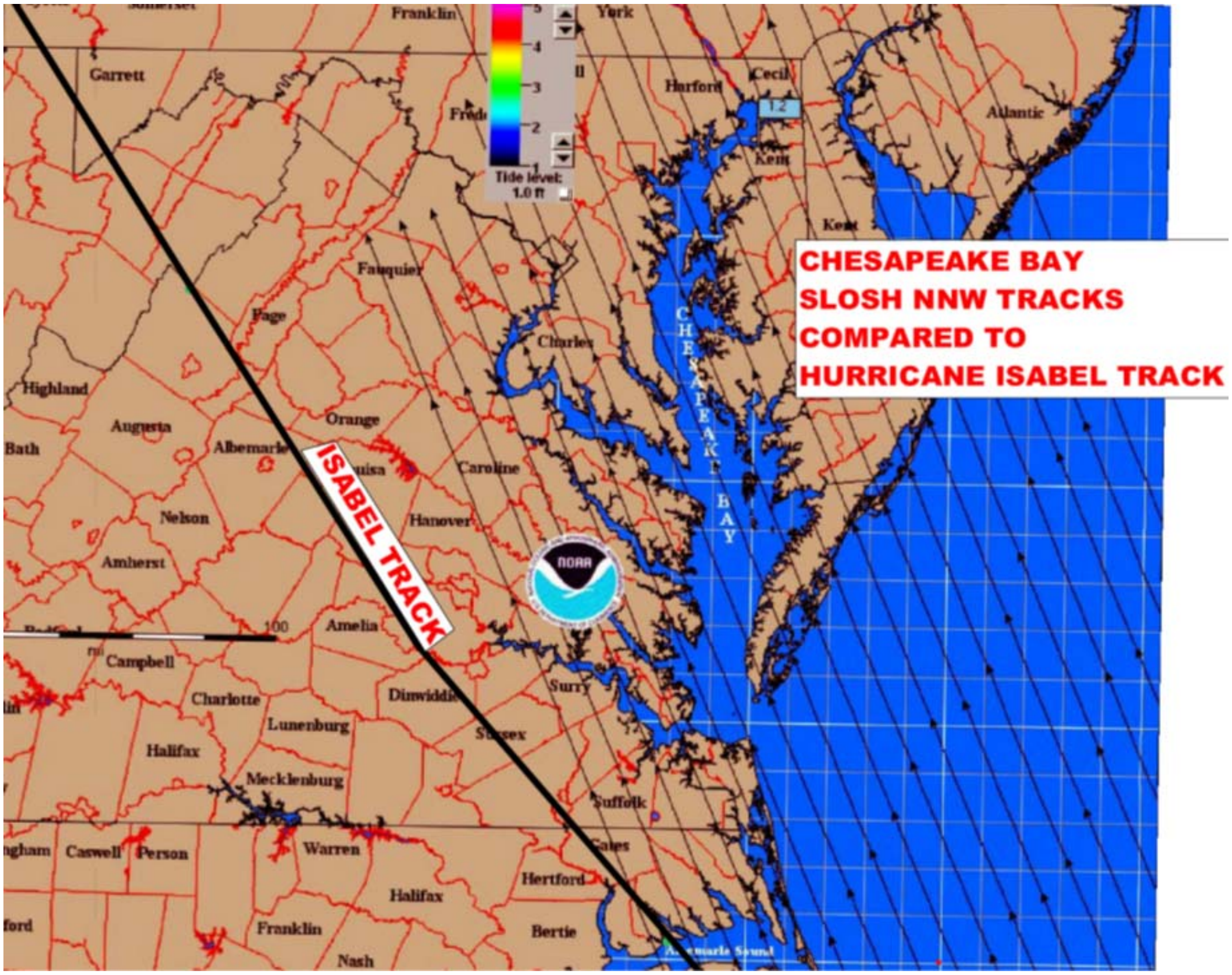
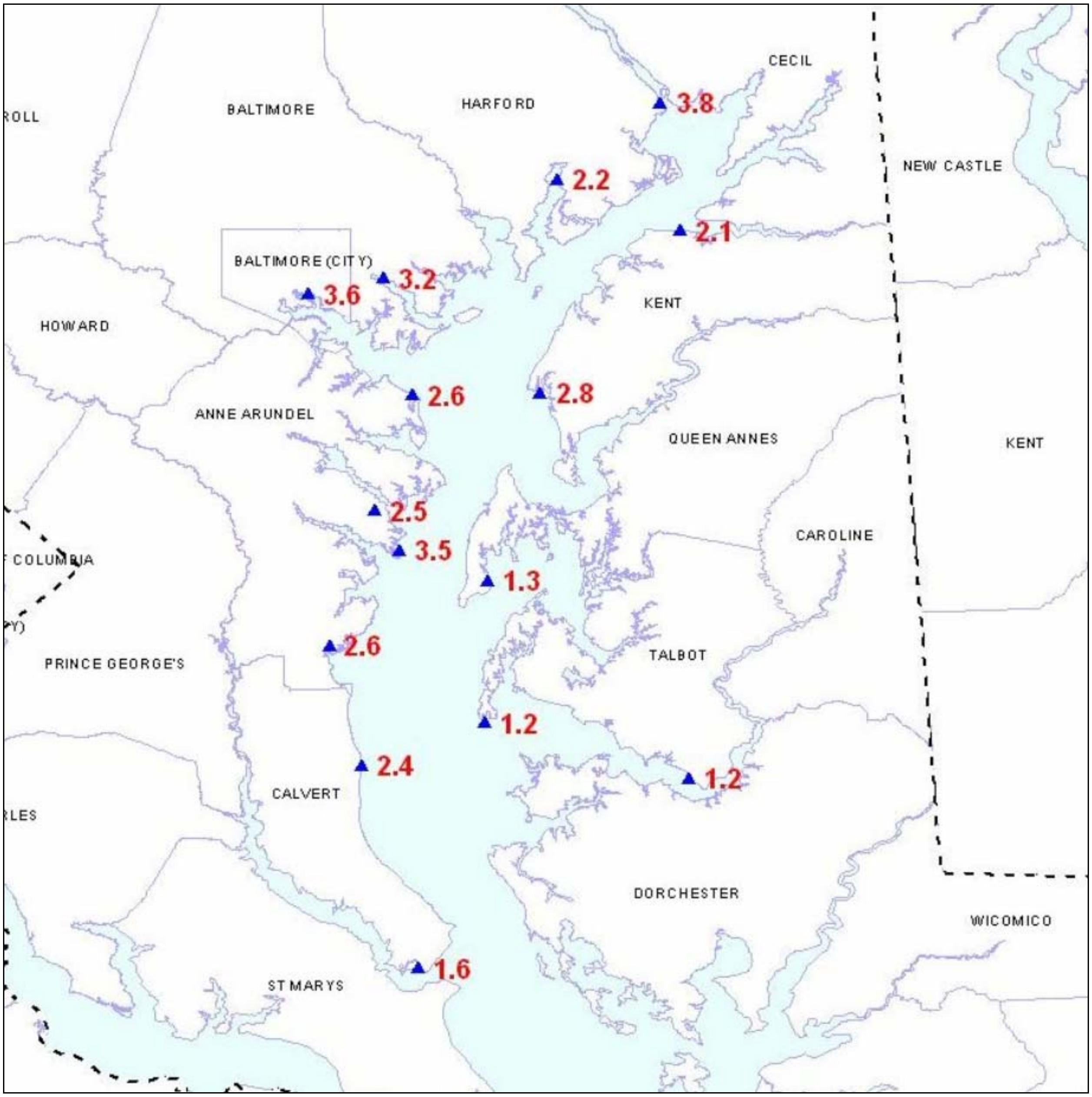


Figure 3-2. SLOSH Display Image of Hurricane Isabel Track Versus SLOSH NNW Tracks



Despite Isabel's "miss", portions of Upper Bay counties began to experience tidal flooding during the night of Thursday, September 16 and well into Friday morning. Last minute, emergency evacuations of bayside communities on both sides of the Bay and numerous locales well upstream on streams and rivers became necessary. Instead of expected tropical storm flood heights, Isabel was producing water levels significantly above SLOSH worst case category 1 MOM (maximum of the maximums) elevations and, in some cases, above the worst case category 2 maximums (See Figure 3-3).

Figure 3-3. Isabel Peak Water Surface Levels – Feet Above SLOSH Category 1 MOMs



Storm Tide Flooding and SLOSH (Sea, Lake and Overland Surges from Hurricanes)

In order to document this storm tide event and assess the use and utility of the SLOSH Model in the applicable basins, post-Isabel high water mark surveys were conducted in North Carolina, Virginia and Maryland. The survey teams were instructed to obtain as many "still water marks" as possible. Still water marks generally reflect the storm tide elevation without the effect of waves. However, because of time delays and the resultant post-Isabel clean-up efforts many of these marks were lost. As a result "debris line" elevations, which generally are taken on the outside of buildings or where debris piles have been created by the rise in water, were obtained when a still water mark could not. Debris line elevations are generally higher than high water marks because of waves. About 70 percent of the high water marks are debris line observations. Overall the coverage of the high water marks is very good with many of them being located in the sections of the rivers where some of the highest storm tide occurred. The marks were screened, and the wave-infected ones were eliminated. This resulted in a final total of 397 marks.

The reference datum used for the high water marks in this study is the National Geodetic Vertical Datum of 1929 or NGVD29. This is where sea-level was in 1929 and this was the "zero" elevation. Since 1929 the tide gauges along the Atlantic seaboard and inside of Chesapeake Bay have indicated a rise in sea-level on the average of about 0.75 feet. To take the rise in sea-level into account for the high water marks, all of the Isabel SLOSH model simulations will include 0.75 feet in their initial water elevations.

<u>SLOSH Model Run</u> - Using Isabel's track, central pressure and radius of maximum winds (RMW) as input data a SLOSH model run was made in both the Pamlico Sound and the Chesapeake Bay basins. Comparisons of the SLOSH results with observed high water mark data in Pamlico Sound and the lower part of Chesapeake Bay showed typical results. However, the comparison in the upper or northern part of the Bay showed the SLOSH values as being much too low. This suggested that the model wind speeds were too low and this in turn suggested that the model input parameters for this part of the SLOSH basin would not generate the observed wind. To compensate for this in the SLOSH model, the track and RMW remained the same but the pressure was adjusted so that the storm surge observed at Baltimore Harbor and Annapolis,

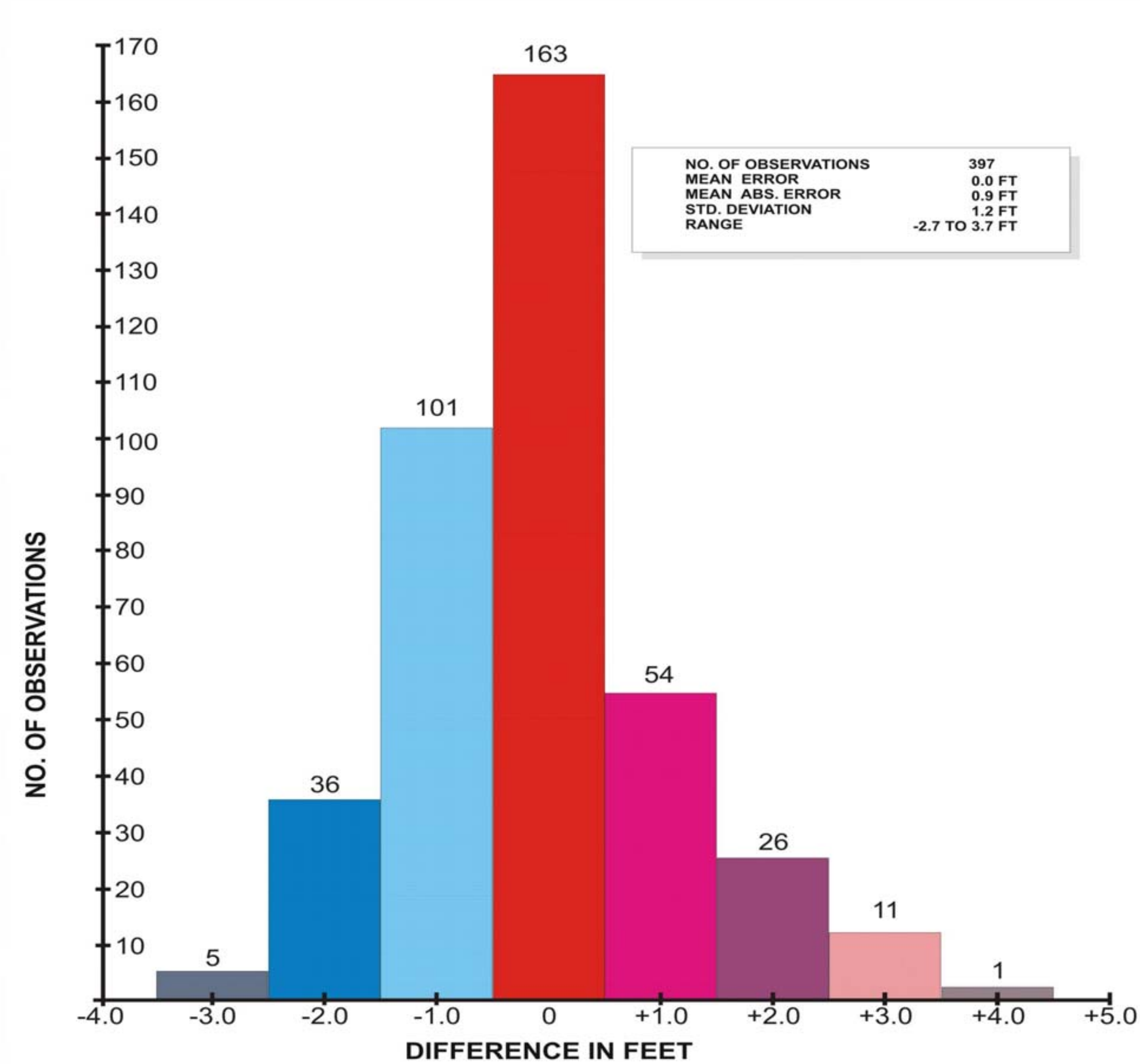
Maryland were very close to the SLOSH calculated values. This compensation resulted in increased wind speeds which were slightly higher than the observed wind data in Baltimore Harbor (see next section).

Observed Surface Wind Profiles Over Water - Three locations in the region recorded wind data over water that are co-located with tide gauges. These locations are unique because most wind recording sites are located inland and have frictionally modified winds. These locations are the eastern end of the Duck pier, the Chesapeake Bay Bridge Tunnel (CBBT) and the Francis Scott Key Bridge (FSKB) over Baltimore Harbor.

The anemometers at the three sites were at different heights. The Duck pier and the CBBT site had their anemometers close enough to the standard 10 meter elevation above mean sea level that no adjustment was made to the wind speeds. The FSKB site is located on the bridge at an altitude of 275 feet above mean sea level. The winds from this site were reduced to the 10 meter level by a logarithmic wind profile formula. For example, the observed wind maximum at 275 feet of a one-minute sustained wind of 76 mph (with a gust to 90 mph) was reduced to 62 mph at the 10 meter level. The wind speed trace at each site was compared to the one-minute sustained wind speed from the SLOSH model for that site. This is the wind speed used in the model (along with a direction) to calculate the wind stress terms that drive the water. The comparisons are reasonable but a bias occurs in the SLOSH model calculated wind near the maximum observed values. The SLOSH model is over-calculating the wind speed by about 8 to 11 mph when compared to the observed.

Comparison of Observed High Water Marks to SLOSH/Tide Values - SLOSH model runs were made in both basins. The maximum SLOSH/Tide calculated value in a particular grid cell was compared to the observed high water mark located in the same cell. The 397 pairs of values were subtracted from each other (i.e. SLOSH/Tide minus observed) and a bar graph of the differences was created and is shown in Figure 3-4. The error characteristics are indicated in the legend. Eighty (80) percent of the differences fall between plus 1.5 to minus 1.5 feet while 96 percent are in the range plus 2.5 to minus 2.5 feet.

Figure 3-4. **SLOSH/Tide Values Minus Observed High Water Marks for Hurricane Isabel (2003) With No Waves**



Comparison of Tide Gauge and SLOSH Storm Surge Hydrographs - Hydrographic records from 27 tide or river gauges in the region of Isabel's impact were obtained. Observed storm surge hydrographs were created from the gauges and these were compared to the SLOSH model-generated storm surge hydrographs for the same location based upon Hurricane Isabel input parameters. However, the initial water elevation for these SLOSH model runs were set to zero elevation because we are comparing storm surges only. The results are provided in Table 3-2 and further discussed in the conclusions below.

Table 3-2. Comparison of Observed and SLOSH Storm Surge Maximums and Time of Occurrence

Station Name	Gauge MAX (ft)	Time of Gauge MAX (UTC)	SLOSH MAX (ft)	Time of SLOSH MAX (UTC)	Gauge Time minus SLOSH Time (hrs)
Annapolis, US Naval Academy, MD	6.3	9/19/03 12:00	6.4	9/19/03 12:00	0
Baltimore, MD	7.3	9/19/03 12:00	7.2	9/19/03 12:00	0
Cambridge, Choptank River, MD	5.2	9/19/03 10:00	4.6	9/19/03 15:00	-5
Cape Hatteras Fishing Pier	NA	NA	5	9/18/03 16:00	NA
Chesapeake Bay Bridge Tunnel, VA	4.8	9/18/03 20:00	4.7	9/18/03 19:00	-1
Chesapeake City, MD	8.2	9/19/03 14:00	6.6	9/19/03 21:00	-6
Colonial Beach, Potomac River, VA	NA	NA	6.9	9/19/03 6:00	NA
Duck USACE FRF, NC	4.7	9/18/03 16:00	4.6	9/18/03 17:00	-1
Gloucester Point, York River, VA	NA	NA	7.5	9/18/03 23:00	NA
Kiptopeke, Chesapeake Bay, VA	3.9	9/18/03 20:00	5.4	9/18/03 21:00	-1
Lewes, DE	3.1	9/19/03 1:00	3.4	9/19/03 2:00	-2
Lewisetta, Potomac River, VA	4.0	9/19/03 1:00	4.9	9/19/03 3:00	0
Money Point, Elizabeth River, VA	5.7	9/18/03 22:00	4.4	9/18/03 22:00	0
Oregon Inlet Marina, NC	4.7	9/19/03 3:00	4.3	9/18/03 22:00	5
Philadelphia, PA	5.4	9/19/03 8:00	4.7	9/19/03 16:00	-8
Pollockville, NC	5.6	9/18/03 23:00	6	9/18/03 21:00	2
Reedy Point, DE	5.0	9/19/03 5:00	7.4	9/19/03 10:00	-5
Richmond Locks, VA	10.8	9/19/03 5:00	6.8*	9/19/03 6:00*	-1
Sewells Point, VA	5.6	9/18/03 21:00	6.8	9/18/03 22:00	-1
Ship John Shoal, NJ	4.7	9/19/03 3:00	6.4	9/19/03 9:00	-5
Solomon Island, MD	NA	NA	5	9/19/03 7:00	NA
Swift Creek, NC	5.0	9/19/03 0:00	5.4	9/19/03 0:00	0
Tolchester Beach, MD	6.9	9/19/03 13:00	6.8	9/19/03 13:00	0
Wachapreague, VA	5.0	9/18/03 21:00	5	9/18/03 23:00	-2
Washington, NC	6.2	9/19/03 0:00	7	9/19/03 3:00	-3
Washington, DC	8.1	9/19/03 10:00	8	9/19/03 14:00	-4
Windmill Point, VA	NA	NA	7.6	9/18/03 23:00	NA
* Comparison not at same location. 5 locations NA means incomplete record. Gauge time differences in last column.					

Conclusions - Comparison of the SLOSH model winds to two over-the-water observing sites, Duck, North Carolina, and the Chesapeake Bay Bridge Tunnel, showed reasonable results, with the SLOSH model maximum wind about 10 mph higher than the observed. With these winds, the SLOSH model produced very reasonable storm surge hydrographs when compared to the observed. However, the maximum winds observed at the northern end of Chesapeake Bay were much larger than standard wind decay models calculated. When the SLOSH model wind field was adjusted to produce the observed wind field (i.e. with a 10 mph high bias), the storm surge results improved dramatically in the northern end of the Chesapeake Bay.

For Hurricane Isabel (2003), comparison of 397 observed high water marks (i.e. wave contaminated marks removed) in North Carolina, Virginia and Maryland yielded typical storm surge model error characteristics, with differences between the observed high water marks and the SLOSH/Tide generated values showing that 80% of the values fall between plus 1.5 to minus 1.5 feet and 96% are within plus 2.5 to minus 2.5 feet.

Comparison of the maximum observed storm surge from tide gauges to the SLOSH model-calculated storm surge maximum showed reasonable results except at two locations in the Delaware Bay - Reedy Point and Ship John Shoal and two locations in the Chesapeake Bay - Kiptopeke and Money Point. Comparison of the time of observed maximum storm surge to the time of the SLOSH-generated maximum in Table 3-2 above showed significant differences in errors in time between gauges near the coast and gauges in the rivers. The results show very good phase comparisons for the coastal locations but a large negative lag in the rivers. In other words, the storm surge in the SLOSH model is arriving many hours late when compared to the observed, even though the maximum heights of the storm surge are very reasonable when compared to each other at these locations.

Wind Effects

Based solely on official measurements recorded during Isabel, sustained hurricane force winds were not pervasive, although peak gusts above the 74 mph threshold were extensive and observed in all three of the surveyed states. It must also be noted that wind records from the most seriously affected areas are incomplete as several observing stations were either destroyed or lost power as Isabel passed. Nonetheless, three official weather stations in North Carolina recorded sustained winds at or above hurricane force, two at Cape Hatteras and one at Elizabeth City (see Table 3-2 for specifics).

The tropical-storm force wind ellipse, as mentioned in Chapter 2, extended hundreds of miles from the center of circulation impacting numerous states well outside of the area surveyed for this report. Sustained tropical storm-force winds were reported even as far away as Kennedy and LaGuardia Airports in New York City. With such a large wind ellipse, Hurricane Isabel imposed its effects on numerous jurisdictions for many hours. Based on the windfields provided in the NHC advisories and displayed in HURREVAC, a significant number of communities throughout North Carolina, Virginia and Maryland were subjected to sustained tropical storm-force winds for almost 24 hours. In addition, a tornado was confirmed to have touched down in Norfolk which many have further contributed to the storm's cumulative wind impacts.

Although Isabel's recorded winds on land were not particularly intense, many conditions existed at the time of its arrival which exacerbated the effects of those winds on communities in all three states. There were widespread and sporadic reports of homes damaged by winds, but even more structures were damaged by falling trees. Two years of drought followed by exceptionally wet periods just before the arrival of Hurricane Isabel uprooted a significant number of trees which contributed to the damages suffered throughout the area. The widespread hurricane-force gusts, the duration of the sustained winds and soil conditions all served to amplify the effects of Hurricane Isabel.

Figure 3-5, on the next page provides the peak gust estimates as measured by the Newport / Morehead City, North Carolina, National Weather Service Office (WFO) during Hurricane Isabel.

Figure 3-5. Observed Peak Winds from Newport/Morehead City, NC, WFO

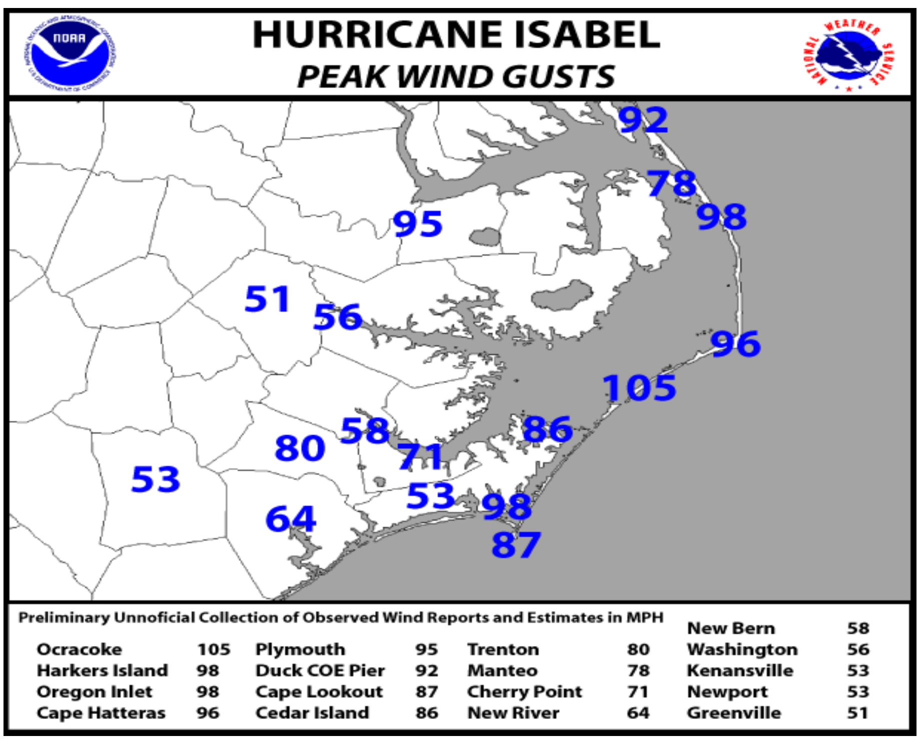


Figure 3-6 below was prepared by the Wakefield, Virginia, office of the National Weather Service as part of their October 9, 2003 Post-storm Report for Hurricane Isabel.

Figure 3-6. Observed Peak Winds from Wakefield, VA, WFO

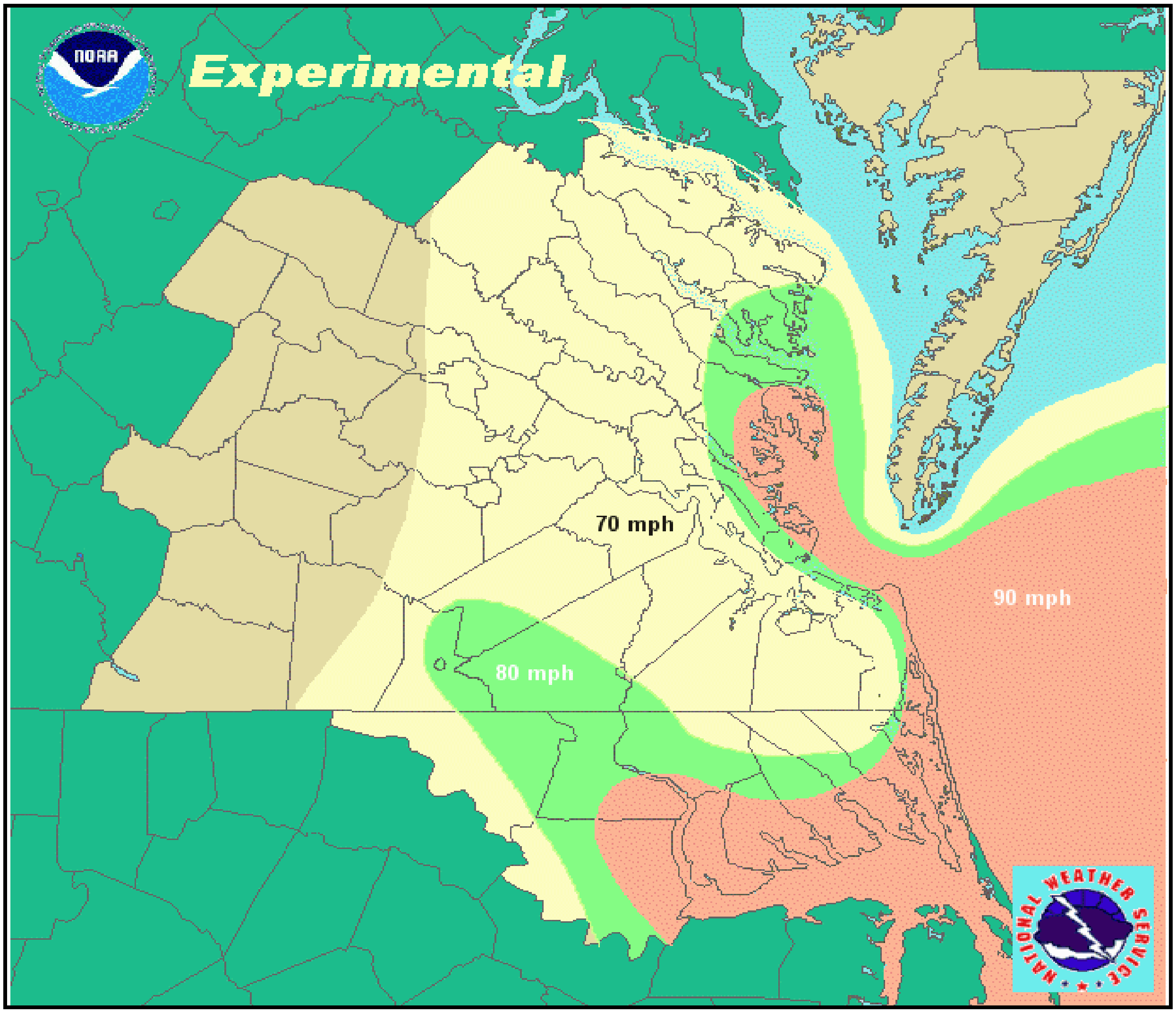


Table 3-3 on the following page is provided by the NHC and documents all official recorded weather gauge readings throughout all the impacted states, including storm surge readings; wind speeds; rainfall amounts; and date/time of maximum observations.

Table 3-3. Selected Surface Observations for Hurricane Isabel

Location	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)					
	Date/ Time (UTC)	Press. (mb)	Date/ Time[a] (UTC)	Sust. Wind[b] (kts)	Peak Gust (kts)	Storm Surge[c] (ft)	Storm Tide[d] (ft)	Rain (storm total) (in)
North Carolina								
Alligator River NWR RAWS			18/1900	50				3.75
Atlantic Beach (Clemson/UF Tower)	18/1645	962.8	18/1558	55	67			
Back Island RAWS			18/1813		53			1.65
Beaufort RAWS			18/1815		64			5.64
Beaufort (NOS)						5.8	2.5	
Burlington (KBUY)					48			
Cape Hatteras (Clemson/UF Tower)	18/1644	968.2	18/1622	69	85			
Cape Hatteras Pier NOS[f]	18/1518	974.0	18/1518	68	83	7.7	5.6	
Caswell Gamelands RAWS			18/2017		46			1.95
Cherry Point (KNKT)	18/1840	968.2	18/1818		62			5.24
Clinton (KCTZ)					40			
Craven Co. (Neuse river)							10.5	
Duke Forest RAWS			18/1907		53			1.70
Duck Corps of EngineersPier NOS[e]	18/1918	984.0	18/2100	55	72	7.8	4.7	4.72
Elizabeth City (KECG)			18/1543	51[e]	64[e]			2.72
Elizabeth City (Clemson/UF Tower)	18/1940	981.9	18/1852	64	84			
Elizabethtown			18/2320	22	43			2.26
Erwin-Dunn (KHRJ)					38			
Fayetteville (KFAY)				35	50			
Fort Bragg (KFBG)					52			
Fort Bragg RAWS			18/2007		48			1.33
Franklinton (KLHZ)					39			
Goldsboro (KGSB)				35	51			
Greensboro (KGSO)					40			
Greens Cross RAWS			18/1708		50[e]			6.29
Greenville (KPGV)			18/1855	34	44			5.75
Henderson (KHNZ)					39			
Hoffman Forest RAWS			18/1509		50			2.35
Laurinburg (KMEB)					35			
Lumberton (KLBT)			18/1921	32	45			3.39
Manteo (KMQI)	18/1743	982.4	18/1843	44	68			
Nature Conservancy RAWS			18/1658		54			1.91
New Bern (KEWN)			18/1608		50[e]			

	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)					
Location	Date/ Time (UTC)	Press. (mb)	Date/ Time[a] (UTC)	Sust. Wind[b] (kts)	Peak Gust (kts)	Storm Surge[c] (ft)	Storm Tide[d] (ft)	Rain (storm total) (in)
North Carolina (continued)								
New River (KNCA)	18/1756	981.7	18/1556	39	56			2.02
Newport (KMHX)	18/1730	968.9	18/1800		46			5.87
Nature Conservancy RAWS			18/1658		54			1.91
New Bern (KEWN)			18/1608		50[e]			
New River (KNCA)	18/1756	981.7	18/1556	39	56			2.02
Oregon Inlet Marina NOS						4.7	5.4	
Pocosin Lake NWR RAWS			18/1823		64			5.94
Raleigh (KRDU)					39			
Rocky Mount (KRWI)				35	54			
Rocky Mount RAWS			18/2113		52[e]			4.20
Roanoke Rapids[e] (KRZZ)			18/2147	38	55			
Sanford (KTTA)					43			
Smithfield (KJNX)					34			
Sunny Point RAWS			18/2158		51			2.09
Turnbull Creek RAWS			18/2313		41			2.19
Washington (KOCW)	18/1944	963.5	18/1803	37	49			
Wilmington (KILM)	18/1843	990.5	18/2143	39	51			1.98
Wilmington (Clemson/UF Tower)	18/1730	990.8	18/1315		43			
Virginia								
Back Bay NWR RAWS			18/1935	38	53			4.12
Blacksburg (WFO)			19/0120		34			
Chesapeake Bay Bridge Tunnel NOS	18/2154	992.4	18/2048	52	64	4.8	7.5	
Colonial Beach NOS[e]						3.7 (6.5)[h]	5.4	
Culpeper (KCJR)	19/0303	995.0						
Danville (KDAN)			18/1922		45			
Dulles Airport (KIAD)	19/0359	997.6	19/0122	32	42			1.96
Fort Belvoir (KDAA)								2.32
Fredericksburg (KEZF)								2.79
Gloucester Point NOS[e]						6.4	8.3	
Gloucester Point (VIMS)			18/2200	60	79			
Great Dismal Swamp RAWS			18/1945		39			
Kingsmill NOS[e]						4.3	6.6	
Kiptopeake NOS			18/2342	39	60		6.5	
Langley AFB (KLFI)	18/2348	991.9	18/1808	46	66			2.67

	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)					
Location	Date/ Time (UTC)	Press. (mb)	Date/ Time[a] (UTC)	Sust. Wind[b] (kts)	Peak Gust (kts)	Storm Surge[c] (ft)	Storm Tide[d] (ft)	Rain (storm total) (in)
Virginia (continued)								
Leesburg (KJYO)			19/0444		42			
Lewisetta NOS[e]	19/0012	997.3	19/0100	46	59	3.0	3.7	
Manassas (KHEF)	19/0335	997.0						
Melfa (KMFV)	18/2102	1000.0						
Money Point NOS			18/2318	38	52	5.7	8.3	
Newport News[e] (KPHF)	18/2237	990.2	18/1756	38	57			3.16
Norfolk Airport[e] (KORF)	18/2151	990.2	18/2049	41	64			2.50
Norfolk N.A.S. (KNGU)			18/2110	50	72			4.21
Oceana N.A.S. (KNTU)	18/2056	990.9	18/2056	48	60			
Portsmouth	18/2225	987.2						
Quantico (KNYG)	19/0355	996.8	19/0322	47	67			
Roanoke (KRNK)			18/2143		38			
Rappahannock Light NOS	18/2354	995.4	18/2318		60			
Richmond (KRIC)			19/0013	33	63			4.32
Scotland NOS[e]						4.8	6.8	
Sewells Point NOS	18/2130	991.4	18/1642	50	64	5.6	7.9	
Wakefield (KAKQ)								5.76
Wallops Island (KWAL)	19/0012	1003.1	18/1747	43	54			0.80
Wachapreague NOS[e]	18/2300	1001.8				2.5	5.5	
Wakefield WFO								5.66
Washington Reagan Airport (KDCA)	19/0359	999.3	19/0139	39	50			2.31
Windmill Point NOS							3.8	
District of Columbia								
National Academy of Science (DCNet)				19/ N/A	62			
Washington NOS							7.9	
Maryland								
Andrews AFB (KADW)			18/2051	33	60			
Annapolis NOS						6.3	7.2	
Baltimore NOS						7.3	8.2	
Baltimore (KBWI)	19/0358	1001.4	19/0211	38	48			3.21
Black NWR RAWS			18/2227		40			1.42
Cambridge NOS[e]	19/0154	1003.0	18/2054	37	49	5.2	6.2	2.20
Chesapeake City NOS						4.9	5.7	
Frederick			19/0543		43			
Hagerstown (KHGR)	19/0548	998.6	18/2328	34	45			

	Minimum Sea-level Pressure		Maximum Surface Wind Speed (kt)					
Location	Date/ Time (UTC)	Press. (mb)	Date/ Time[a] (UTC)	Sust. Wind[b] (kts)	Peak Gust (kts)	Storm Surge[c] (ft)	Storm Tide[d] (ft)	Rain (storm total) (in)
Maryland (continued)								
Maryland Science Center (KDMH)	19/0301	1002.4						
Ocean City (KOXB)	18/2257	1006.1	18/2252	36	46		6.5	1.97
Patuxent River (KNHK)	19/0355	999.0	19/0355	48	60			
Salisbury (KSBY)	19/0331	1005.1	18/2009	32	44			2.08
Silver Springs (DCNet)			19/ N/A		72			
Solomons Island NOS[e]	19/0018	1000.7	19/0106	45	56			
Tolchester Beach NOS	19/0354	1003.2	19/0124		38	6.9	7.9	

See below for footnotes

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min; NOS stations averaging periods are 6 min; RAWS stations report 10 min average sustained winds.
[c] Storm surge is water height above normal tide level.
[d] Storm tide is water height above mean low low water (MLLW).
[e] Incomplete record - more extreme values may have occurred
[f] Station destroyed - more extreme values may have occurred
[g] 10-min average
[h] Subsequent Survey Storm Surge value
[i] 15-min average
[j] Estimated

Rain and Freshwater Flooding

According to the NHC Summary Table above, North Carolina recorded extremes that varied from 1.33 inches in Fort Bragg to a maximum of 6.29 inches. Virginia's rainfall minimums and maximums as documented above were 0.8 inches at Wallops Island to 5.76 at the Wakefield WFO; although other stations in the Wakefield and Sterling WFO reporting areas recorded significantly higher totals, including one reading of 20.20 inches in Upper Sherando. These high total rainfall amounts resulted in widespread flooding in numerous communities with additional reports of flash flooding incidents also occurring during the storm. Maryland's observed figures in Table 3-1 ranged from 1.42 to 3.21 inches. These rainfall amounts reportedly caused localized flooding along the Potomac and Monocacy Rivers and Seneca Creek.

Figure 3-7 is a map of the rainfall amounts and their distribution as estimated by the Doppler radar at the Newport / Morehead City, North Carolina NWS Office.

Figure 3-7. Newport / Morehead City, NC, WFO Hurricane Isabel Rainfall Estimate

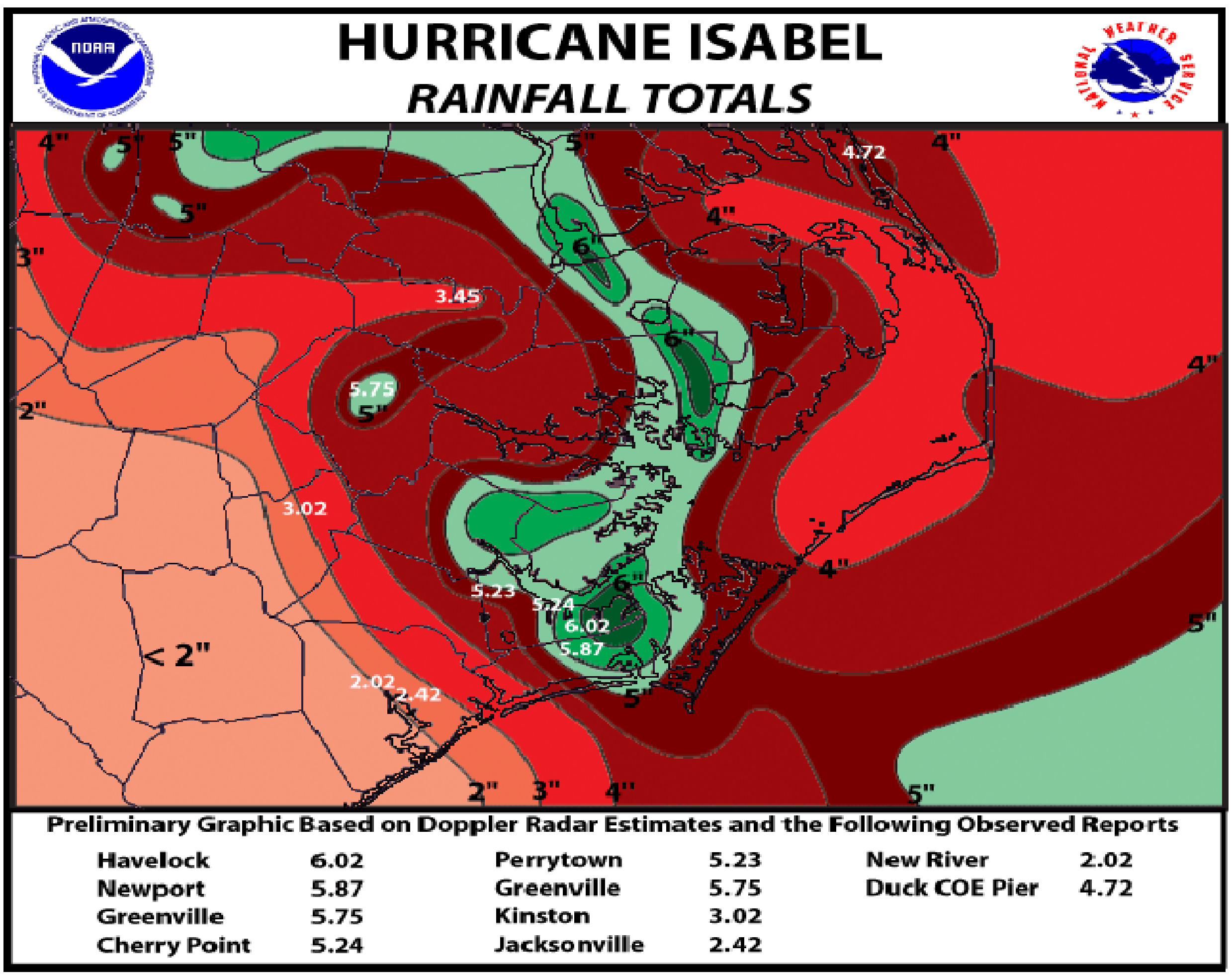


Figure 3-8 below depicts the distribution of rainfall for the Wakefield, Virginia, NWS Office's area during Hurricane Isabel.

Figure 3-8. Wakefield, VA, WFO Hurricane Isabel Total Rainfall Estimates

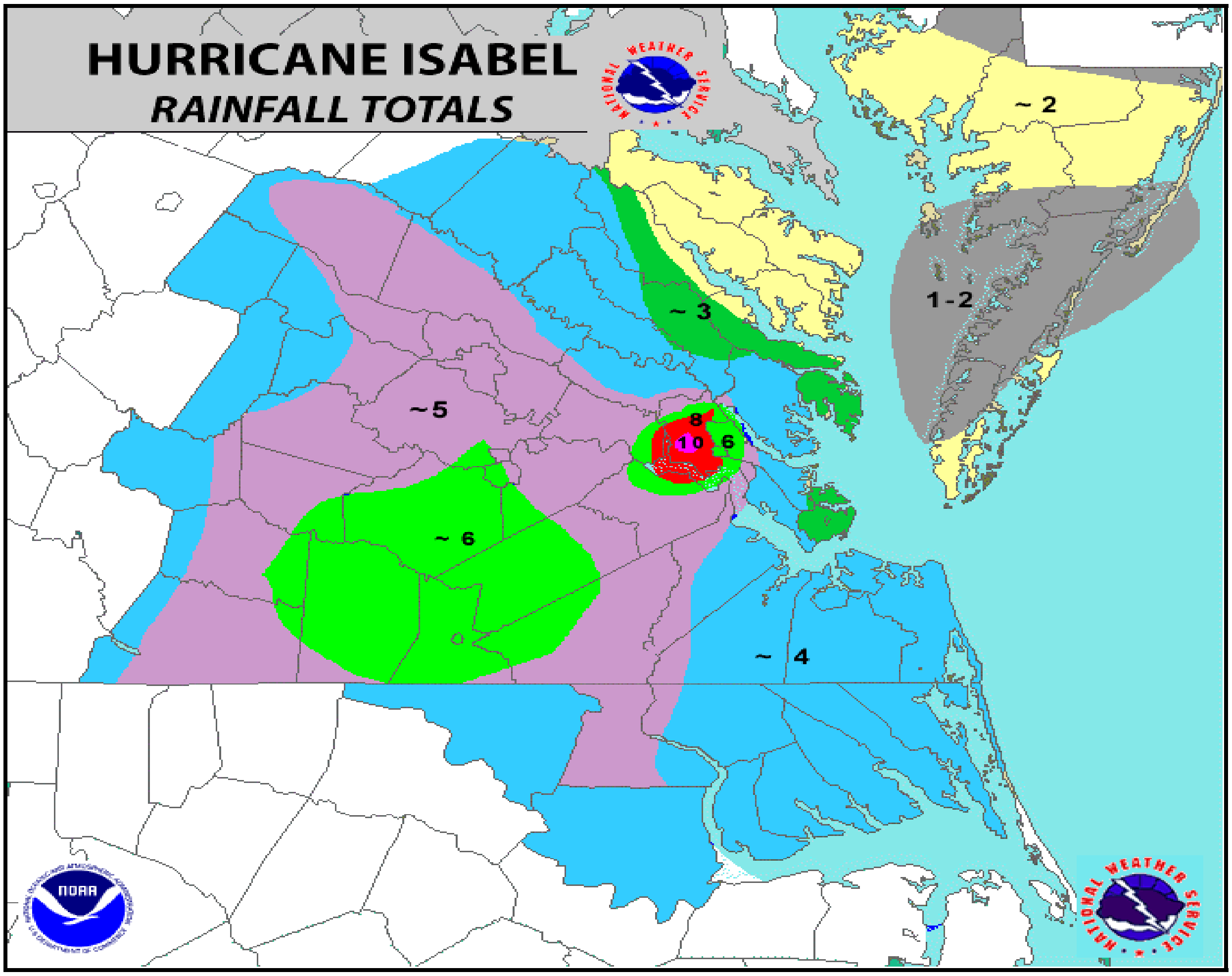
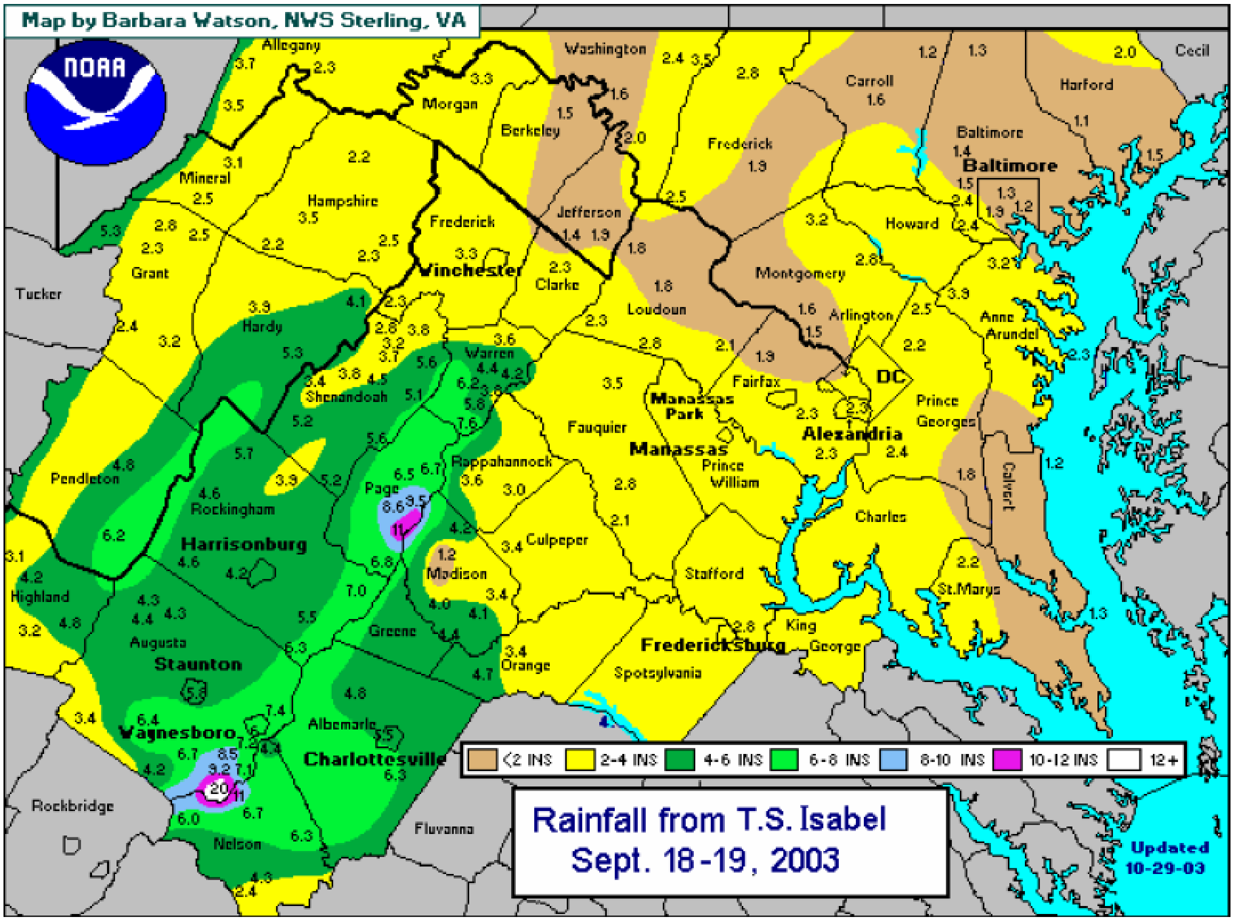


Figure 3-9 below shows the measured amounts and the distribution of rainfall throughout the Sterling, Virginia NWS Office area for Hurricane Isabel.

Figure 3-9. Sterling, VA, WFO Hurricane Isabel Total Rainfall Estimates



Recommendations

With the exception of the Upper Chesapeake Bay, storm surge heights observed during Hurricane Isabel were in reasonable agreement with levels indicated by SLOSH model runs used as the basis for hurricane evacuation study storm surge mapping and evacuation zones. For the Upper Chesapeake Bay Isabel surge heights were significantly higher than those used for HES mapping. Analyses by the National Weather Service (Tropical Prediction Center/National Hurricane Center; Atlantic Oceanographic and Meteorological Laboratories; National Oceanographic and Atmospheric Administration Corps) have established that the higher than expected surges in the Upper Chesapeake were caused by Isabel's exceedingly large Radius of Maximum Wind (RMW), particularly as the storm moved into northern Virginia, eastern West Virginia and western Pennsylvania. These increasingly large RMWs, which had not been observed in other historical hurricanes in this region, produced tropical storm-force winds with a long fetch over the Chesapeake. Isabel's Radius of Maximum Winds at landfall in North Carolina (1 PM EDT, Thursday, Sept 18) was 52 statute miles and it continued to expand as it moved inland. However, RMWs used in the Chesapeake Bay Basin in support of HES storm surge mapping have previously not exceeded 30 miles.

Forecast uncertainty and the inexact nature of weather phenomenon impose further difficulties in interpreting meteorological data and using it for decision making. The SLOSH model and any other human attempt at predicting meteorological conditions cannot foresee or emulate every possible permutation of the atmosphere and the surface that it interacts with, especially with a complex system such as a tropical cyclone. Even minor variations in an effectively infinite number of variables that can exist in a hurricane will have major repercussions on the impact that the associated hazards can have on populations and property. Therefore, state and local decision makers must be continuously educated on hurricane hazards and forecast uncertainty and how to factor that inexactness into their decision making processes. In that respect, future hurricane training should emphasize that SLOSH-based inundation mapping is based on hypothetical storms using normal or typical characteristics and that actual storm conditions may deviate dramatically from those modeled variables. Additionally, local government officials must be ready to take advantage of real-time information resources relative to storm data, as well as the actual observed conditions in making protective action decisions for their jurisdictions.

Based upon the above results regarding storm tides and the SLOSH models it is recommended that the National Hurricane Center undertake the following actions:

1. **Recommendation: Review, update and improve the resolution of the current SLOSH study for the Chesapeake Bay.**

2. **Recommendation: Incorporate hypothetical hurricanes, similar to Isabel, into the Chesapeake Bay SLOSH model to determine the potential storm tide impacts, especially for the northern end of the basin.**

3. **Recommendation: Generate new SLOSH Maximum Envelopes of Water (MEOWs) and Maximum of the Maximums (MOMs) for use in determining changes to existing hurricane evacuation zones**.

Chapter 4
Protective Action Decision Making

Probably the most important products developed as part of the FEMA/USACE Hurricane Evacuation Study (HES) process and delivered to state and local governments are the evacuation decision making tools. Decision arcs, HURREVAC and the Evacuation Traffic Information System (ETIS) provide state and local emergency management agencies (EMAs), as well as other government agencies, with the information needed to affect better protective action decisions and execute the procedures necessary to implement them. These tools provide the capability to access and apply the HES study data during actual tropical cyclone events without necessarily having to browse through the voluminous amount of material in a Technical Data Report.

Another aspect of hurricane protective action decision making is the technical assistance which the National Hurricane Mitigation and Preparedness Program (NHMPP) provides to state and local governments during actual hurricane events. The Hurricane Liaison Team (HLT) and Evacuation Liaison Team (ELT) are a cadre of trained and experienced subject matter experts who are available to assist officials interpret meteorological and HES-related data and arrive at an appropriate course of action in response to a specific tropical cyclone threat.

Discussions initiated by the FEMA/USACE study teams with local and state officials concentrated on the following questions in the protective action decision making process:

- When was the Emergency Operations Center (EOC) fully activated?
- Were evacuations ordered and when were they issued?
- What prompted the decision to evacuate?
- What study products / decision aids where used to decide when to initiate protective actions such as evacuations? and
- What study products / decision aids where used to decide what populations were subject to protective actions?

Table 4-1 below provides a summary of the relevant responses and information gathered from each community.

Table 4-1. Summary of Survey Responses for Decision Making

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
NORTH CAROLINA						
Beaufort Co.	Partial: 9/16;4 PM Full: 9/17; 4 PM	**Recommended: 9/17; 4 PM** Cat 3 Surge; MH; River/Lake Fronts; Flood Areas	HES / Surge Maps; History of Flooding; History of Wind Damage; Local Knowledge of County	Shelter Locations; SLOSH; Tides; Local Plan; HURREVAC; Surge Maps; Radar Net	Shelter Locations; **SLOSH; Tides;** Local Plan; Clearance Times; **HURREVAC; Websites**	No [2]
Bertie Co.	Full: 9/17;12 PM	**Recommended**: **no date specified** Cat 2 Surge; MH Voluntary; Flood Areas	HES / Surge Maps; History of Flooding; History of Wind Damage; Political Decision	Shelter Locations; HURREVAC; Surge Maps	**HURREVAC**; Surge Maps; **Websites**	No
Brunswick Co.	Partial: 9/17	**Voluntary: 9/17; 2 PM** MH; River/ Lake Fronts; Islands; Beach Fronts; Flood Areas	History of Flooding; History of Wind Damage; Political Decision	Shelter Locations; SLOSH; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	Shelter Locations; Clearance Times; **HURREVAC**; **Websites**	No [3]
Camden Co. & Pasquotank Co.	Full: 9/17; 2 PM	**Voluntary: 9/16; 3 PM Mandatory: 9 /17; 2 PM** Countywide	HES / Surge Maps; History of Wind Damage; NWS Info	Shelter Locations; SLOSH; Local Plan; HURREVAC; Surge Maps	**HURREVAC**; Storm Surge Maps; Local Plan; **Websites; NWS**	No
Carteret Co.	Partial: 9/16; 6 AM Full: 9/17; 5 AM	**Voluntary: 9/16**; **7 AM Mandatory: 9/17; 7 AM** MH; Healthcare Facilities; Beach Fronts; Flood Areas	History of Flooding; History of Wind Damage; Political Decision	Shelter Locations; SLOSH; Clearance Times; HURREVAC; Surge Maps	**SLOSH; HURREVAC**; NWS	No
Chowan Co.	Full - no date specified	**Recommended - no date specified** MH	History of Flooding; Political Decision; NWS Info	HURREVAC	**HURREVAC**; Websites; NWS	No

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
NORTH CAROLINA (Continued)						
Craven Co.	Full: 9/17; 8 AM	**Voluntary: 9/16** Low –lying Areas; Flood Areas; Specific Identified Neighborhoods	HES / Surge Maps; FIRMs; History of Flooding; History of Wind Damage	ETIS; SLOSH; Local Plan; HURREVAC	Shelter Locations; Local Plan; Clearance Times; **HURREVAC**; Surge Maps; **NWS**; DTN	No [4]
Currituck Co.	Partial: 9/15; 8 AM Full: 9/15; 8 AM	**Mandatory: Outer Banks – 9/16;12 PM Mainland - 9/17; 10 AM**	HES / Surge Maps; History of Wind Damage	Evac Maps; Clearance Times; HURREVAC	**HURREVAC;** Local Plan; Hurrtrak	No
Dare Co.	Partial: 9/15; 8 AM Full: 9/17; 5 AM	**Mandatory: 9/17; 12 PM** Countywide	History of Flooding; Political Decision	SLOSH; Evac Maps; Local Plan; Clearance Times; HURREVAC	**SLOSH; Tides;** Clearance Times; **HURREVAC**	No [3]
Hyde Co.	Partial: 9/16; 12 PM Full: 9/17; 6 PM	**Voluntary: 9/16; 12 PM Mandatory: 9/17; 8 AM** Mandatory Countywide	HES / Surge Maps; History of Flooding	SLOSH; Evac Maps; Local Plan; HURREVAC**;** Surge Maps	**SLOSH**; **HURREVAC**; **NWS & NHC Websites**	No
Jones Co.	Partial: 9/16; 5 PM Full: 9/17	**Voluntary** Low-lying areas; MH; Special Needs; Flood Areas	History of Flooding	HURREVAC	**HURREVAC**; **NWS**	No
Martin Co.	Partial: 9/17; 5 PM Full: 9/17; 6 PM	**None Ordered**	Not Applicable	Local Plan; SLOSH; HURREVAC	**HURREVAC**; **NWS & DOT Websites**	No [2]
New Hanover Co.	Full: 9/17; 12 PM	**None Ordered**	Not Applicable	HURREVAC	**HURREVAC**	No

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
NORTH CAROLINA (Continued)						
Onslow Co.	Partial: 72 hours before forecast landfall Full: 9/16; 6 PM	**North Topsail Beach only; Voluntary on 9/17** Islands; Beach Fronts; Flood Areas	HES / Surge Maps	ETIS; Shelter Locations; Evac Maps; SLOSH; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	Shelter Locations; **SLOSH**; Local Plan; **HURREVAC**; **Websites**	Probably Not
Pamlico Co.	Partial: 9/16/03; 8 AM Full: 9/17; 3 PM	**Voluntary: 9/17; 3 PM** Low-lying areas; MH; Healthcare Facs; Flood Areas	HES / Surge Maps; History of Flooding	Shelter Locations; SLOSH; Evac Maps; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	**SLOSH**; Evac Maps; Clearance Times; **HURREVAC**; DTN	Yes [5]
Pender Co.	Partial: 9/17; 6 AM Full: 9/17; 5 PM	**Surf City Voluntary Evac on 9/17; County decided not to**	HES / Surge Maps; History of Flooding; Political Decision	Shelter Locations; SLOSH; Evac Maps; HES; Clearance Times; HURREVAC; Surge Maps	Local Plan; **HURREVAC**	No [3]
Perquimans Co.	Partial: 9/16; AM Full: 9/17; 12 PM	**Recommended - no date specified** MH; River/Lake Fronts	History of Flooding; History of Wind Damage; Political Decision	Shelter Locations; SLOSH; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps;	Local Plan; **HURREVAC**	No
Tyrell Co.	Full: 9/17; 8 AM	**Mandatory: 9/17; 12 PM** Cat 2 Surge; MH; Healthcare Facs; River/ Lake Fronts; Islands; Flood Areas	Political Decision; HURREVAC; Actions in Dare Co.	Local Plan; HURREVAC; Surge Maps	Local Plan; **HURREVAC**; Surge Maps; **Websites**	No

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
NORTH CAROLINA (Continued)						
Washington Co.	Partial: 9/17; 8 AM Full: 9/18; 8 AM	**Mandatory: 9/17; 5 PM** MH; River/ Lake Fronts; Beach Fronts; Flood Areas	HES / Surge Maps; FIRMs; History of Flooding	Shelter Locations; SLOSH; Local Plan; Clearance Times; HURREVAC; Surge Maps	**HURREVAC**; **NWS Website**	No
North Carolina Division of Emergency Management	Full: 9/17; 12 PM	Counties make that determination for their own jurisdictions	Counties make that determination for their own jurisdictions	ETIS; Shelter Locations; SLOSH; Evac Maps; HES; Clearance Times; HURREVAC; Surge Maps	**SLOSH**; Clearance Times; **HURREVAC**; **NWS Websites; HAZUS** (by Director NCDEM)	No [6]
VIRGINIA						
Accomack Co.	Partial: 9/17; 9 AM Full: 9/18; 6 AM	**Voluntary: 9/17; 12 PM** [7] MH; Healthcare Facs; River /Lake Fronts; Islands; Beach Fronts; Flood Areas	HES / Surge Maps	Shelter Locations; SLOSH; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps	**SLOSH**; Local Plan; Clearance Times; **HURREVAC**; **NWS Buoy & NOAA Websites**	No
Chesapeake	Partial: 9/17;12 PM Full: 9/18; 3 AM	**Mandatory: 9/17; 11 AM** [7] Cat 2 Surge; MH; River /Lake Fronts; Flood Areas	HES / Surge Maps; FIRMs; History of Flooding; Political Decision [7]	Shelter Locations; SLOSH; Evac Maps; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	Shelter Locations; **SLOSH**; Evac Maps; Local Plan; HES; Clearance Times; **HURREVAC**; Surge Maps; **Websites**	No
Chincoteague	Full: 9/18; 6 AM	**Voluntary: 9/17; 12 PM** [7] MH; Healthcare Facs; River /Lake Fronts; Islands; Beach Fronts; Flood Areas	Surge Maps; History of Flooding	Shelter Locations; SLOSH; Evac Maps; Local Plan; Clearance Times; HURREVAC	**HURREVAC; SLOSH/Tides**; **Websites**	No

Survey Community	EOC activation date and time	Date – Time OF Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
VIRGINIA (Continued)						
Gloucester Co.	Partial: 9/17; 5 PM Full: 9/18; 6 AM	**Recommended: 9/17; 6 PM** [7] Cat 4 Surge; MH; River /Lake Fronts; Flood Areas	Surge Maps; History of Flooding; History of Wind Damage	Shelter Locations; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps	Local Plan; Clearance Times; **HURREVAC**; Surge Maps; **Tides**; **Websites**	No
Hampton	Partial: 9/15; 12 PM Full: 9/17; 5 PM	**Mandatory: 9/1712 AM** Cat 2 Surge; MH; River /Lake Fronts; Flood Areas	History of Flooding; History of Wind Damage; Discussion Among City Agencies	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	**HURREVAC**; **SLOSH/Tides**; Surge Maps; Shelter Locations; Evac Maps; Local Plan; Clearance Times; HES [8]; **Websites**	No
Isle of Wight Co.	Partial: 9/17; 8 AM Full: 9/17; 5 PM	**Voluntary: 9/17; 11 AM** [7] Beach fronts; MH; Flood Areas	FIRMs; History of Flooding	Shelter Locations; Evac Maps; Local Plan; HURREVAC	Local Plan; **HURREVAC; Websites**	No
Lancaster Co.	Partial: 9/16; 9 AM Full: 9/18; 9 AM	**Voluntary: 9/17; 10 AM** [7] Cat 1 Surge; Beach Fronts; Flood Areas	FIRMs; History of Flooding	Shelter Locations; Local Plan; HURREVAC; Surge Maps	Shelter Locations; Local Plan; **HURREVAC**; Surge Maps; **Websites**	No
Mathews Co.	Partial: 9/16; Full: 9/17; 4 PM	**Voluntary: 9/17; 10 AM** [7] MH; Islands; Beach Fronts; Flood Areas	HES / Surge Maps; FIRMs; History of Flooding	Shelter Locations; SLOSH; Evac Maps; Local Plan; HURREVAC; Surge Maps	**SLOSH**; Local Plan; **HURREVAC**; Surge Maps; **Websites**	No

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
VIRGINIA (Continued)						
Newport News	Partial: 9/16; 8 AM Full: 9/17; 4 PM	**Yes, Not Specified** **Mandatory**: MH; Flood Areas **Recommended:** Healthcare Facs; River /Lake Fronts; Islands; Beach Fronts	HES / Surge Maps; FIRMs; History of Flooding; History of Wind Damage; Political Decision	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps; GIS; Hurrtrak	**SLOSH/Tides;** Evac Maps; Clearance Times; **HURREVAC**; Surge Maps; **Websites**	No [2,3]
Norfolk	Partial: 9/16; 8 AM Full: 9/17; 11 AM	**Mandatory:** **9/17; 11 AM** [7] Low Lying Areas	[9]	[9]	[9]	[9]
Northumberland Co.	Full: 9/16; 12 PM	**Voluntary:** **9/17; 11 AM** [7] MH; Flood Areas	History of Flooding; Local Plan	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	Local Plan; **Tides HURREVAC; Websites**	No
Poquoson	Partial: 9/17; 12 PM Full: 9/17; 6 PM	**Recommended:** **9/17** [7] MH; River /Lake Fronts; Beach Fronts; Flood Areas	HES / Surge Maps; History of Flooding; History of Wind Damage; Political Decision	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps	Shelter Locations; **SLOSH/Tides**; Evac Maps; Local Plan; Clearance Times; **HURREVAC**; Surge Maps	No
Portsmouth	No Info Provided	**Voluntary:** **9/17; 8 AM** [7] Cat 2 Surge; MH; River /Lake Fronts; Flood Areas	HES / Surge Maps	Shelter Locations; SLOSH	**SLOSH**; Local Plan; **HURREVAC**;	No

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
VIRGINIA (Continued)						
Richmond Co.	Full: 9/16; 12 PM	**Voluntary: 9/17; 11 AM** [7] Flood Areas	History of Flooding; Local Plan	Shelter Locations; SLOSH; Evac Maps; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	Local Plan; **HURREVAC**; Surge Maps; **Websites**	No
Suffolk	Partial: 9/17; 10 AM Full: 9/17; 4 PM	**Voluntary: 9/17; 11 AM** [7] Cat 2 Surge; MH; Flood Areas	HES / Surge Maps; Political Decision	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; HES; Clearance Times; HURREVAC; Surge Maps	**Tides;** Evac Maps; Local Plan; **HURREVAC**; Surge Maps; **Websites**	No
Virginia Beach	No Info Provided	**Mandatory: 9/17 11 AM** [7] Cat 2 Surge; MH; River /Lake Fronts; Flood Areas	HES / Surge Maps; FIRMs	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps	**SLOSH; Tides**; Local Plan; **HURREVAC**;	No
Westmoreland Co.	Full: 9/16; 12 PM	**Mandatory: 9/17; 10 AM** [7] Flood Areas	History of Flooding; Local Plan	Shelter Locations; Local Plan	Local Plan; **Websites**	No
York Co.	Partial: 9/16; 1 PM Full: 9/18; 5 AM	**Recommended: 9/17;11 AM** [7] Cat 2 Surge; MH; Beach Fronts; Flood Areas	HES / Surge Maps; FIRMs; History of Flooding	SLOSH; Evac Maps; HES; Clearance Times; HURREVAC; Surge Maps	**Tides; HURREVAC; Websites**	No
Virginia Department of Emergency Management	Partial: 9/15 Full: 9/16	Counties make that determination for their own jurisdictions	Counties make that determination for their own jurisdictions	Shelter Locations; SLOSH/Tides; Evac Maps; Local Plan; Clearance Times; HURREVAC	**SLOSH**; **Tides** Clearance Times; **HURREVAC**; **Websites**	Yes

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
MARYLAND						
Anne Arundel Co.	Full: 9/16; 1200	**No Evacuations Ordered**	No Evacuations Ordered	SLOSH; Local Plan; HURREVAC	**SLOSH**; **HURREVAC; NWS, TWC, Tidal Websites**	No
Baltimore Co.	Partial: 9/17; 7 AM	**Recommended:** [10] **Date-time not known** Healthcare Facs; River/Lake Fronts; Beach Fronts; Flood Areas	Not provided	Shelter Locations; SLOSH; Local Plan; HURREVAC; Surge Maps; GIS	Shelter Locations; **HURREVAC**; **Websites**	No
Baltimore City	Partial: 9/17; 8 AM Full: 9/18; 8 AM	**No Evacuations Ordered** (although some evac'ed spontaneously)	No Evacuations Ordered	Shelter Locations; SLOSH; Local Plan; Surge Maps	Shelter Locations; Surge Maps; **NWS, NOAA Websites**	No
Calvert Co.	Partial: 9/16; 7:30 AM Full: 9/17; 6 AM	**Mandatory: 9/18; 12 PM** Specific areas and communities identified	History of Flooding	Shelter Locations; Evac Maps; Local Plan; Clearance Times; HURREVAC	Local Plan; **HURREVAC; Websites**	No
Charles Co.	Full: 9/18; 3 PM	**Recommended: 9/18; 9 PM Mandatory: 9/18; 10 PM** Low-Lying Areas; River/Lake Fronts; Islands; Beach Fronts; Flood Areas	Surge Maps; History of Flooding	Shelter Locations; SLOSH; Evac Maps; Local Plan; Clearance Times; HURREVAC; Surge Maps	SLOSH; Evac Maps; **HURREVAC**; **Websites; NWS**	Yes
Harford Co.	Full: 9/18; 9 AM	**No Evacuations Ordered**	No Evacuations Ordered	Shelter Locations; SLOSH; Local Plan; HURREVAC; Surge Maps	Shelter Locations; **FIRMs**; Local Plan; **HURREVAC; Websites**	No

Survey Community	EOC Activation Date And Time	Date – Time Of Evacuation / Ordered Zones	Means Of Determining Evac Areas	HES Tools Available/Used In Decision Making	Most Useful Information / Decision Tools[1]	Use Of HLT
			MARYLAND			
Howard Co.	Partial: 9/12	**No Evacuations Ordered** (Maybe 6 homes asked to evacuate)	No Evacuations Ordered	Shelter Locations; Evac Maps; Local Plan	Local Plan; **NOAA Website; Flood Warning Gauge System**	No
Prince George's Co.	Partial: 9/11 Full: 9/17	**No Evacuations Ordered**	No Evacuations Ordered	Shelter Locations; State Plan; Rain Gauge Monitors; Accu-Weather	Shelter Locations; **NWS**	No
Somerset Co.	Partial: 9/16 Full: 9/18; 8 AM	**Smith Island Recommended: 9/17**	History of Flooding; Surge Maps	HURREVAC; Shelter Locations; Surge Maps	Local Plan; NOAA Website; HURREVAC; NWS/Wakefield	No
St. Mary's Co.	Partial: 9/15; 7 AM Full: 9/18; 7 AM	**Voluntary: 9/18 Recommended: 9/18** Cat 4 Surge; MH; Beach Fronts; Flood Areas; Countywide	Surge Maps	Shelter Locations; Local Plan; Surge Maps	Shelter Locations; Local Plan; Surge Maps; **Websites**	No
Maryland Emergency Management Agency	Partial: 9/15 Full: 9/17; 8 AM	Counties make that determination for their own jurisdictions	Counties make that determination for their own jurisdictions	Shelter Locations; SLOSH; State Plan; Clearance Times; HURREVAC	SLOSH; State Plan; **HURREVAC; Websites**	Yes

1 Highlighted selections are HES/NHMPP products considered by local officials to be useful AND were specifically used to arrive at a protective action decision during the Hurricane Isabel event.
2 Indirect contact through EOC.
3 Specifically indicated that they would like to be contacted and interact with HLT.
4 Only contacted HLT to discuss discrepancy between forecast and HURREVAC display.
5 Accessed teleconference post-landfall through DFO.
6 Director of NCDEM may have participated in video teleconferences.
7 At 11 AM on 9/17 Governor authorized counties to issue evacuation orders; they become mandatory when issued under his authority.
8 In ranked order.
9 Information obtained from presentation, specific information not provided.
10 Evacuation ordered when hazards were impacting community and need became evident.

The surveys also queried state and local government representative about what new issues should be addressed in subsequent HES efforts for their jurisdictions, based on the experiences gained during Hurricane Isabel. Below are the major issues that became apparent during the surveys and the recommendations to address them:

1. During interviews with emergency management in all three surveyed states, there was a considerable amount of confusion regarding the appropriate use of the Storm Tide Atlases, the SLOSH Display Program and the evacuation zone maps for decision making. For determining local community protective actions, an inordinate amount of emphasis was placed on the need for real-time SLOSH runs and the need to issue them earlier; providing better guidance on what datum to use for high tide determinations; the difficulty of using the SLOSH Display Program; and the relative inaccuracy of the storm tide inundation limits relative to the forecast for Hurricane Isabel.

   As discussed in the previous chapter, the SLOSH (Sea, Lake and Overland Surges from Hurricanes) model is a hurricane hazard assessment tool that predicts the elevation and inland extent of storm tides for various categories of storm intensity. The SLOSH data determines what areas in a community are subject to abnormally high tides for each category of storm. That data is then compiled to develop maps and atlases that depict storm tide inundation limits. Local governments then use the inundation limits in their storm tide maps to delineate evacuation zone boundaries and identify which populations must evacuate in response to a particular category of hurricane intensity. The evacuation zone boundaries, which are tied to clearly identifiable landmarks and physical features within the community, should then be used by local officials specifically for protective action decision making as a tropical cyclone approaches.

   Very little discussion during the surveys focused on the use of evacuation zones and the maps that depict the boundaries for those areas. For protective action decision making, emergency management should use evacuation zone maps and not the SLOSH data in .rex files or Maximum Envelope of Water (MEOW) formats. The SLOSH data, primarily in maximum of maximum (MOM) format, should be used by emergency management to delineate the evacuation zones very early on in the HES process, well before the arrival of a specific hurricane threat. Unfortunately, the HES for Virginia and the Western Shore of Maryland were still very early in the study process during Hurricane Isabel. Consequently, the communities in Virginia had not yet updated the zones in their 1992 study and the local governments along Maryland's Western Shore had no evacuation zones to work from at all. More than a year after Isabel, because of funding shortfalls the communities in both study regions are still waiting to delineate or update their evacuation zones.

Nonetheless, many of the surveyed jurisdictions with evacuation zones delineated in their HES indicated that they did not use them during Hurricane Isabel. This finding is troubling because it undermines the fundamental utility of HES clearance times. The evacuation zones are the basic unit used to determine the size of the vulnerable population and the numbers of vehicles involved in an evacuation for a particular category of storm. Major variations in the areas directed to evacuate by local officials during a particular hurricane event may have a major impact on the accuracy of clearance times used for protective action decision making. Since HES clearance times determine the lead time needed before the arrival time of tropical storm-force winds to safely conduct an evacuation, any deviation in applying the study data may have negative consequences for public safety.

The primary utility of storm tide MEOW data, either as .rex files or from the SLOSH Display Program, is for preliminary impact and damage assessment. MEOW data is too specific, relies heavily on the accuracy of hurricane forecasting and provides little latitude for public safety with respect to normal errors and uncertainties in the meteorology. Therefore, SLOSH MEOW data should be used for assessing the risk and exposure of critical facilities and property to storm tides, not for the extemporized determination of which populations are vulnerable to a particular tropical cyclone's hazards.

The HES process and the NHMPP in general must institute an aggressive training program for local and state emergency management regarding the appropriate use of storm tide inundation limit data and evacuation zones. To use real time SLOSH runs or MEOW data from the SLOSH Display Program for ad hoc evacuation zone determinations during an actual storm event is very much against best practices and may result in major public safety problems. As seen with the storm surge issues described in the northern reaches of

Chesapeake Bay, hurricane science and forecasting is still fraught with enough uncertainty that improvised decisions regarding which populations should evacuate are a dangerous proposition, even with a model as reliable as SLOSH. The Hurricane Program must educate all state and local government officials about the limitations of using SLOSH data for evacuation decision making, as well as stress the importance of using pre-determined evacuation zones as a means to improving the margin of public safety.

Recommendation: Develop an intensive training program for state and local emergency management staff regarding the appropriate use of Storm Tide Atlases, the SLOSH Display Program and evacuation zone maps in evacuation decision making and response operations.

The training must convey to state and local government decision makers that:

a. SLOSH based inundation mapping is based on hypothetical storms with standard parameters, such as radii of maximum winds;
b. Actual storm parameters may vary significantly from those standard parameters; and
c. Evacuation decision makers should pay close attention to "real time" information sources (i.e. local NWS offices, Hurricane Liaison Teams) when assessing the characteristics of threatening storms.

2. Based on comments from certain jurisdictions in all three of the surveyed states, the public and some local government officials were apathetic to the potential impacts of Hurricane Isabel. Some state and local government decision makers, regardless of location or region, have a tendency to discount the hazards of tropical storms and less intense hurricanes. Consequently, there is an increased likelihood that local governments will delay their decision to direct protective actions, or leave it to the discretion of the public. This relaxed response is even more evident in at-risk populations throughout the country, regardless of how frequently they face approaching tropical cyclone events. To some degree this issue is further exacerbated by the media that will frequently post reporters on the beaches to broadcast live images of surfers and other spectators in the areas at risk, or under evacuation orders.

Again the solution to this issue is primarily an educational one. The NHMPP must convince local government officials, the media and the general public at large that there is a difference in sustained wind speed of only one mile per hour between a tropical storm and a hurricane. All constituents of the Program must also be educated that storm tides in certain tropical storms can be worse than in higher categories of hurricanes. Also, tropical storms can and have deluged communities with prodigious amounts of rainfall and caused widespread destruction with tornados and other wind phenomenon.

Recommendation: Develop a comprehensive campaign to impress on the public and local decision-makers alike that the dangers associated with tropical storms and lesser category hurricanes may warrant protective actions.

3. A consistent message from all local governments participating in this survey is that almost none of them were aware of the existence or activation of the HLT during Hurricane Isabel, much less used it for protective action decision making. Nonetheless once local governments in all three survey states were educated on the HLT's potential utility, they definitely expressed an interest in having access to the tele-conferences, as well as other information or services they provide.

   All three of the surveyed state emergency management agencies participated in the daily video conference calls between the HLT, the states and the Emergency Support Team (EST) at FEMA headquarters in Washington, D.C. However, there were no indications from any local governments in the surveyed states that there was any interaction between them and the HLT, or that they were even given the opportunity to passively participate in the video conference calls. Clearly, with respect to the HLT, local governments did not directly benefit by its activation during this particular disaster, especially with respect to decision making.

   At its inception, the HLT was specifically created to act as a liaison between the NHC and state and local governments during hurricane events. The HLT was originally intended as a resource for state and local governments to consult in getting technical assistance from the NHC for decision making and response activities. Another original anticipated mission for the team was to advocate state and local operational issues and concerns to the NHC forecast specialists during the development of the tropical cyclone advisories.

The above observations from local governments clearly indicate that the focus of the HLT is mainly directed at federal and state emergency operations, rather than the disaster response activities of local governments. Historically, the reasons for this are in response to objections raised by some states regarding the potential for undermining coordination efforts between their EOCs and those of their local governments. Therefore, the Team has evolved into more of an information gathering resource for the Federal Response Plan and less as a liaison element between the NHC and the state and local governments that must use the hurricane advisory data for public safety and response purposes. The HLT, instead of coordinating a conference call from the NHC to state and local governments as a means to discuss the hurricane advisory package and its implications for public safety, primarily establishes a video teleconference call from the Center to the EST, on which the State EOCs are invited to participate.

In discussions with team coordinators and members regarding the lack of widespread interaction between the NHC/HLT and local governments, an almost universal explanation is an unwritten FEMA policy decision that forbids direct contact between the HLT and local governments. This policy decision was a result of the above stated misgivings by a few states regarding the coordination problems that such contact might engender. Nonetheless, despite this no-direct-local-government-contact policy for the HLT, the post-Isabel response survey forms specifically ask questions of local emergency managers and responders regarding the Team and the quality of the services provided. The lack of knowledge among local governments regarding the existence of the HLT was pervasive, despite a major storm and a reasonably untried group of communities with respect to hurricanes. Either the FEMA no-contact policy is working and very effective, thereby negating the need to even ask these questions of local governments in the surveys, or there is a discrepancy in the real mission of the HLT.

A significant amount of the equipment used by the HLT at the National Hurricane Center is in support of the video teleconference calls with the EST and the State EOCs. Furthermore a considerable amount of effort by team members during an approaching hurricane event is devoted to the preparation and conduct of those federal and state agency coordination events.

These video conference calls are usually once a day and don't always coincide with the issuance of the NHC's Tropical Cyclone Advisory Package (5 AM, 11 AM, 5 PM and 11 PM for every day a tropical cyclone exists). Certainly these events are not performed in a timely manner relative to protective action decision making or pre-landfall response activities at the state or local government levels. In order to actively participate in this important function of the HLT, the participants must have video conference capability. Unfortunately this equipment is rarely found at a local government EOC.

The one responsibility that the HLT can assume is to conduct telephone conference calls with state and local EMAs coincident with the issuance of the NHC advisories during a storm. The HLT has the means to set up telephone conference calls between the NHC and the many local and state governments that would benefit greatly by having the opportunity to interact with the hurricane specialists at these critical times during a hurricane. Nonetheless, for Hurricane Isabel, the HLT did not perform even this function for the local governments in North Carolina, Virginia or Maryland. This direct information exchange between the specialists at the NHC and local government decision makers would likely increase the margin of safety for the public as a tropical cyclone approaches and protective actions must be considered and implemented. This interaction would be especially helpful to local officials in states that do not frequently exercise their hurricane protective action decision making process.

The National Oceanographic Survey in their CO-OPS 040 Report on the storm tide elevations recorded during Hurricane Isabel, states that, "Official NWS and NHC forecasts accurately predicted and warned of major storm surges and wind events in the Mid-Atlantic States, including the Chesapeake and Delaware Bays." Given this statement, either those surge predictions were not clearly conveyed to the applicable local governments, or the officials in those communities did not fully comprehend the information as it was provided. A stronger link between the HLT and local governments during Isabel may have provided the information needed to encourage more proactive decisions in response to the storm tide issues in the upper Chesapeake Bay.

Recommendation: Review and/or communicate the real missions of the HLT and develop the procedures and technical capabilities to support those

roles. If a mission of the HLT is to provide local governments with assistance in protective action decision making and the interpretation of technical data during tropical cyclone events, then the NHMPP must dramatically improve its efforts to increase awareness about the existence and use of the team.

4. During hurricane events, rather than deploying Disaster Assistance Employees (DAEs) only to the NHC to act as the liaison with state and local governments, the HLT should station trained members to the EOCs in at-risk states and possibly local governments. At the request of a state, or local government, the HLT could assign representatives from FEMA, the U. S. Army Corps of Engineers (USACE), as well as other non-impacted state Hurricane Program managers to those EOCs to act as an on-site technical advisor, similar to the Risk Analyst position assigned to the Region IV Regional Operations Center (ROC) during hurricane events. These deployed representatives would predominantly deal with emergency management issues and concerns, such as running and interpreting HURREVAC; analyzing evacuation and other important response data for the client agency; and coordinating with the HLT and ELT. These field team members could be self contained and fully equipped with computers, communications and administrative office equipment and sent to an EOC with all of the clearance time and other data necessary to assist in decision making, evacuation management and other pre-landfall response operations.

Given the relative inexperience of some surveyed state and local governments during Hurricane Isabel, many may have welcomed the arrival of a subject matter expert from the NHMPP to help decipher and interpret hurricane-related data. If providing technical expertise and assistance to local governments is indeed the primary mission of the HLT, especially pre-landfall, field deployment may be a more suitable way to fulfill it, both for the state and local governments, as well as the NHC and FEMA.

Recommendation: Create a cadre of NHMPP representatives (USACE, FEMA and State Program Managers) available for deployment to state and local government Emergency Operations Centers (EOC) to act as

on-site technical advisors for hurricane evacuation and response operations.

5. Few local governments have a clearly defined process for determining the necessary protective actions in response to a particular storm threat. This problem is especially true in many Mid-Atlantic and New England states where their HESs are updated less frequently and opportunities to use a decision making process for hurricanes are relatively rare. Florida and Virginia have developed a standardized methodology for considering many of the meteorological, transportation and operational issues in developing protective action decisions during tropical cyclone event. Additionally, during these interviews, the Maryland Emergency Management Agency (MEMA) indicated that they are interested in considering a Hurricane Risk Profile methodology for assessing hurricane related information in their evacuation decision making process.

   In the Hurricane Risk Profile, HURREVAC extracts salient information from the NHC advisory and relates it to evacuation information from the HES to assist local governments in developing an appropriate operational response to a specific tropical cyclone. The decision making criteria for every coastal and inland community, as well as the state as a whole can be included in this module. Such a capability can be very helpful for uninitiated local governments that do not frequently exercise their decision making process, or do not routinely respond to approaching hurricane threats.

   Many of the decision making criteria in the Hurricane Risk Profile are very generic and can apply to any jurisdiction. Therefore, it would be very easy to either modify the existing program to suit all jurisdictions or add specific criteria to better conform to local or regional needs. A Hurricane Risk Profile in HURREVAC would be another tool available to emergency management in arriving at, or justifying a protective action decision based on the meteorological conditions specific to an impending hurricane threat.

   Recommendation: Develop a generic version of the Hurricane Risk Profile in HURREVAC that is applicable to all state and local governments to increase consistency in decision making during actual tropical cyclone events.

6. A complaint lodged by the state EMA representatives was that the HLT video teleconference calls with the EST were too long. Toward the end of the post-hurricane response, as more states and communities were being declared, the status description by the states during these video conference calls was requiring more time. This was particularly a problem for states further down in the conference roll call list that had to wait for all the previous states to complete their reports. The participating EMA staff in these later states indicated that they were devoting too much time to participating in the conference calls, discussing their response activities with the EST, rather than actually performing them. The states are requesting that the HLT develop a more streamlined format that does not require the same level of detail and limits the amount of time each state is allowed to discus their issues.

   Recommendation: Develop a more streamlined format for conducting the video conferences between the HLT, the states and the EST.

Chapter 5
Hurricane Evacuation Study and Hurricane Program Products

Hurricane Evacuation Studies (HES) not only comprise the paper documents, the Technical Data Report (TDR) and the Technical Support Document, that are the final result of a study effort, but also the other tools and aids used by state and local governments to effect better hurricane preparedness and response plans. Additionally, the National Weather Service (NWS) products are also included in this discussion, since they form the basis for the hazards analysis part of the HES. This chapter will evaluate the end user's perception of the various products that are a result of the HES effort and determine what actions are necessary to improve them.

A HES Technical Data Report is composed of the following components:

- ► Hazards Analysis: which evaluates the hurricane-induced hazards and their impacts on the study communities.
- ► Vulnerability Analysis: which quantifies the populations at risk for the above hazards.
- ► Behavioral Analysis: which captures the behavioral characteristics of at-risk populations with respect to their perception of the hurricane risks, their responses to emergency directives from government officials, and their courses of action in certain evacuation scenarios.
- ► Shelter Analysis: which identifies a community's public shelter facilities, their capacities and vulnerability to surge or freshwater flooding.
- ► Transportation Analysis: which integrates salient data from each of the previous components into a comprehensive traffic model that emulates the evacuation roadway network under various hurricane-induced travel demand scenarios. Clearance times, an important result generated by the model, establish the lead time necessary to complete an evacuation before hurricane conditions begin to escalate within a community.
- ► Decision Arcs: which provide a method to determine when a community must initiate protective actions based on forecast data for a specific storm.

Under the National Hurricane Mitigation and Preparedness Program (NHMPP), FEMA, the USACE, the National Weather Service (NWS) and the Federal Highway Administration (FHwA) collaborate to prepare the above components of an HES or to assist state and local governments in using the study data to affect better hurricane plans and measures. Among the associated tools that are also used or created as part of the HES process:

- SLOSH Display Program, which provides detailed predicted storm tide elevations and inland extents based on the Maximum of the Maximums (MOM) or the Maximum Envelope of Water (MEOW).

- Tides Program, which runs within the SLOSH Display Program, which is a graphical prediction program that displays the height and timing of normal tides for up to three different locations simultaneously.

- Storm Tide Atlases, a direct product of the HES process that provides detailed maps of the inland extent of various categories of storm tides based on the SLOSH MOM data.

- HURREVAC, which is a decision support program that combines the data from the NHC advisory package with HES data to provide the user with the ability to analyze and display decision making criteria against the meteorological characteristics of a particular storm.

- ATM (Abbreviated Transportation Model), a simplified version of the model used for the HES Transportation Analysis which allows local governments to assess the impacts of changes in vulnerable populations and other evacuation related variables on clearance times.

- ETIS (Evacuation Traffic Information System), a travel demand forecast model for hurricane evacuation that allows state and local governments to assess the cumulative impacts of their evacuation decisions on the evacuation roadway network, as well as share information with one another about response actions and traffic management measures.

Another program which only recently was augmented by FEMA to address hurricane issues is the HAZUS Program. HAZUS is a GIS-based hazard analysis tool that assesses the impacts of hurricane-induced hazards on residential, commercial and public property. Its primary function is to assist government responders in anticipating property losses and other resource requirements before a particular hurricane impacts a community, rather than supporting the hurricane protective action decision making process. Using the specific meteorological data provided in the NHC advisory, the software forecasts what property will be impacted by the various hurricane hazards; the magnitude of the damage; the numbers of people affected as well as their socioeconomic characteristics; the volume of debris generated by the destruction; and an estimated cost to restore and rebuild the affected public and private assets in a community. For protective action decision making though, HAZUS has little or no utility.

FEMA only recently provided the wind module of the HAZUS program to local governments. Furthermore, the storm surge and flood modules have not yet been developed and tested. This has made any substantive evaluation difficult because very few state and local governments had the opportunity to use HAZUS for this event. The utility of such a comprehensive program for impact and damage assessment, as well as hazard mitigation may have a revolutionary effect on future events, especially during the response and recovery phase of a disaster. Unfortunately HAZUS like ETIS had only limited distribution and use during this particular event, too limited to evoke any substantive responses from the potential users of the program.

During interviews with the communities in North Carolina, Virginia, and Maryland the survey team asked questions of state and local government representatives about their perceptions of the performance and user friendliness of some of the above programs. The surveys sought to establish which of the above programs were used pre-landfall to assist in evacuation decision making; determine how well they performed; how easy they were to use; and whether the training they received was adequate in preparing them. The responses to those surveys are included in Table 5-1. Using the 1 (low) through 5 (high) ratings provided by the state and local governments in their Post-Isabel surveys the averages for program utility and ease of use are:

HURREVAC:	Performance = 4.6	Ease of Use = 4.3	communities using = 86 %
SLOSH Display:	Performance = 3.8	Ease of Use = 3.7	communities using = 60 %
Tides:	Performance = 4.0	Ease of Use = 4.2	communities using = 42 %

Figure 5-1. Meeting with Local Emergency Management and Response Officials in North Carolina

Figure 5-2. Meeting with Northern Neck, VA Local Emergency Management Officials

Table 5-1. Summary of Survey Responses for HES and NHMPP Products

Survey Community	Used HURREVAC [a]		Used SLOSH Display [a]		Used Tides Program [a]		Used ETIS [a]		Comments On Training
	Performance Rating	Ease of Use Rating	Performance Rating	Ease of Use Rating	Performance Rating	Ease of Use Rating	Performance Rating	Ease of Use Rating	
NORTH CAROLINA									
Beaufort Co.	5	5	4	4	4	4			Adequately Trained On All But ETIS; ETIS Partially Trained
Bertie Co.	5	4	[b]						Partially Trained On HURREVAC
Brunswick Co.	5								Partially Trained On HURREVAC; Need Training On All Others
Camden Co. & Pasquotank Co.	5	4							Partially Trained On HURREVAC; Need Training On All Others
Carteret Co.	5	5	4	4					Adequately Trained On HURREVAC & SLOSH
Chowan Co.	5								Partially Trained On HURREVAC
Craven Co.	5	4 to 5	[b]	3					Partially Trained in HURREVAC; No Training in SLOSH or Other Programs
Currituck Co.	5	5	3	2	2	3	3	[b]	Adequately Trained On HURREVAC & Tides; Partially Trained on SLOSH & ETIS
Dare Co.	5	5	3	4	5	5			Adequately Trained In All Programs
Hyde Co.	5	4	3	3					Partially Trained On HURREVAC & SLOSH
Jones Co.	5	5							Adequately Trained On HURREVAC Except on New Just Added Functions

Survey Community	Used HURREVAC [a]		Used SLOSH Display [a]		Used Tides Program [a]		Used ETIS [a]		Comments on Training
	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	
NORTH CAROLINA (Continued)									
Martin Co.	**4**	**4**							Partially Trained in HURREVAC
New Hanover Co.	**5**	**5**							Partially Trained in HURREVAC
Onslow Co.	**5**	**5**	**5**	**5**	5				Adequately Trained On HURREVAC & SLOSH; Partially on Tides
Pamlico Co.	**5**	**5**	**5**	**5**					Adequately Trained On HURREVAC; Partially Trained on SLOSH; No Training in Other Programs
Pender Co.	**4**	**4**							Adequately Trained On HURREVAC; SLOSH & Tides; ETIS Not Applicable
Perquimans Co.	**4**	**4**							Adequately Trained On HURREVAC & SLOSH; Not Adequately Trained On Others
Tyrell Co.	**1**	**1**							Partially Trained In HURREVAC
Washington Co.	**5**	**5**	3	3					Partially Trained In HURREVAC & SLOSH
North Carolina Division of Emergency Management	**5**	**5**	3	4	3	2	3	3	Adequately Trained On HURREVAC, SLOSH & ETIS; Partially Trained on Tides
VIRGINIA									
Accomack Co.	**5**	**5**	**4**	**3**	**3**	**4**			Adequately Trained On HURREVAC & SLOSH; Not Adequately Trained On Others
Chesapeake	**5**	**5**	**5**	**5**					Adequately Trained On HURREVAC & SLOSH

Survey Community	Used HURREVAC [a]		Used SLOSH Display [a]		Used Tides Program [a]		Used ETIS [a]		Comments On Training
	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	
VIRGINIA (Continued)									
Chincoteague	**4**	**5**	**4**	**3**	**3**	**4**			Adequately Trained On HURREVAC, SLOSH & Tides
Gloucester Co.	**5**	**4**	**4**	**4**	**4**	**4**			Partially Trained On HURREVAC, SLOSH & Tides
Hampton	**5**	**5**	**5**	**5**	**5**	**5**			Adequately Trained On HURREVAC, SLOSH & Tides
Isle of Wight Co.	**5**	**5**							Adequately Trained On HURREVAC
Lancaster Co.	**5**	**5**							Adequately Trained On HURREVAC
Mathews Co.	**4**	**4**	**b**	**b**					Adequately Trained On HURREVAC; No Training Indicated for SLOSH
Newport News	**4**	**4**	**4**	**4**	**4**	**4**			Partially Trained On HURREVAC, SLOSH & Tides
Norfolk	**c**	**c**	**c**	**c**	**c**	**c**			**3**
Northumberland Co.	**5**	**3**	5	2	**5**	**5**			Adequately Trained On HURREVAC & Tides; Partially Trained On SLOSH
Poquoson	**4**	**4**	**4**	**4**	**4**	**b**			Partially Trained On HURREVAC, SLOSH & Tides
Portsmouth	**5**	**5**	**5**	**5**	5	5			Adequately Trained On HURREVAC, SLOSH & Tides
Richmond Co.	**5**	**3**	5	2	5	**b**			Adequately Trained On HURREVAC & Tides; Partially Trained On SLOSH
Suffolk	**5**	**4**	3	**b**	**b**	**b**			Adequately Trained On HURREVAC & SLOSH
Virginia Beach	**5**	**5**	5	5	**5**	**5**			Adequately Trained On HURREVAC, SLOSH & Tides

Survey Community	Used HURREVAC [a]		Used SLOSH Display [a]		Used Tides Program [a]		Used ETIS [a]		Comments On Training
	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	
VIRGINIA (Continued)									
Westmoreland Co.									Partially Trained On HURREVAC
York Co.	**4**	**4**	4	4	**4**	**4**			Adequately Trained On HURREVAC & Tides: Partially Trained On SLOSH
Virginia Department of Emergency Management	**5**	**5**	**4**	**4**	**4**	**5**			Adequately Trained On HURREVAC & Tides; Partially Trained On SLOSH & ETIS
MARYLAND									
Anne Arundel Co.	**4**	**4**	**2**	**4**	**2**	**4**			Adequately Trained On HURREVAC, SLOSH & Tides
Baltimore Co.			**4**	**4**					Partially Trained on HURREVAC & SLOSH
Baltimore City	3	4	1	4	4	4			Partially Trained on HURREVAC & SLOSH
Calvert Co.	4	3							Partially Trained on HURREVAC
Charles Co.	**3**	**2**	2	2	**4**	**4**			Partially Trained On HURREVAC, SLOSH & Tides
Harford Co.	**4**	**4**	2	2					Adequately Trained On HURREVAC; Partially Trained On SLOSH
Howard Co.									No Training On Any Program
Prince George's Co.									No Training On Any Program
Somerset Co.	**4**	**4**			**4**	**4**			Adequately Trained On HURREVAC & Tides
St. Mary's Co.									No Training On Any Program

Survey Community	Used HURREVAC [A]		Used SLOSH Display [A]		Used Tides Program [A]		Used ETIS [A]		Comments On Training
	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	Perfor-mance Rating	Ease of Use Rating	
MARYLAND (Continued)									
Maryland Emergency Management Agency	**5**	**5**	4	4	4	5			Adequately Trained On HURREVAC, SLOSH & Tides

a 1 = lowest rating; 5 = highest rating; Bolded rating numbers indicate that the program was used in decision making for Hurricane Isabel. Grey shaded boxes indicate that the program was not used at all.
b Used but a rating was not provided.
c Information obtained from presentation, specific information not provided.

The surveys also queried state and local government representatives about what new issues should be addressed in subsequent HES efforts for their jurisdictions, based on the experiences gained during Hurricane Isabel. Below are the major issues that became apparent during the surveys and the recommendations to address them:

1. Virginia's HES was completed in 1992 and Maryland's in 1990. Both studies are outdated enough that most emergency managers and local government officials either are not using them, or are not aware that one exists for their jurisdictions. Although restudies are underway in both states, the current rate of funding from the NHMPP will likely extend the time needed to complete one or both of the studies beyond the 2006 fiscal year.

   In the cases of Virginia and Maryland, both states have large urbanized areas at direct risk from hurricanes (the Norfolk-Hampton-Newport News SMA in Virginia, Baltimore-Annapolis in Maryland), adjacent to large metropolitan areas that present significant traffic congestion problems during evacuations (Richmond in Virginia and Washington, D.C. for Maryland and the Delmarva Peninsula) and extensive areas subject to storm surge, especially in the areas around Chesapeake Bay. The potential for major loss of life clearly exists for this entire region, particularly during major hurricane events. Clearly the completion of the Maryland, Virginia and Delmarva studies must be established as high-priority projects in the allocation of future FEMA and USACE funds.

   Recommendation: Expedite completing the HESs for Virginia, Maryland and the Delmarva Region as soon as possible. Any increase in funding for these projects should not be at the expense of study efforts currently underway in the other states with a similar hurricane threat but without the experience of a recent hurricane landfall.

2. Many of the communities on the James, York, Rappahannock and Potomac Rivers not included in the initial Virginia HES area experienced hurricane effects including storm surge during Hurricane Isabel. Consequently, these jurisdictions had to consider implementing protective actions without the benefit of any hard data for evacuation planning or response operations. These communities also had to compete with evacuees from the highly urbanized areas around Hampton Roads for space on I-64 and I-95, further complicating their situation.

Counties further inland, well away from the coast, also may have to relocate their own mobile home or flood-prone residents during future tropical cyclone events, as well as contend with evacuees from the coast. No guidance and planning data has been provided to these communities regarding their needs for protecting their own residents, or dealing with the influx of evacuees from the coast.

Recommendation: Expand the study area for the Virginia HES Restudy to include communities further inland along the tributaries of Chesapeake Bay: the James, York, Rappahannock and Potomac Rivers. The following communities have expressed and interest to be included: the City of Williamsburg, and Isle of Wight, James City and Surry Counties.

3. The NHMPP does not adequately educate local officials on the information contained in an HES, or the application of that data for hurricane preparedness and response planning purposes. All too frequently upon completion of an HES, volumes of study material are delivered to the local emergency management agency (EMA) with little or no detailed training provided to the other officials and decision makers in the community.

   Recommendation: Develop a training program as part of the HES study process that continually educates state and local officials regarding the use of study products and tools.

4. There is a wide range of quality in the ground elevation data used to map SLOSH model storm surge inundation limits. The default data set used is the U.S. Geological Survey's National Elevation Data (NED) Set. The NED has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format (see http://ned.usgs.gov/). The NED is continually updated as improved ground elevation data is developed.

   The usual source for the NED elevation data is the 7.5 minute USGS quadrangle. In some cases, these maps have a five-foot elevation contour interval - from which digital elevation models of reasonable resolution and accuracy may be derived. However, the majority of quadrangles have 10-foot contour intervals. In the typically flat coastal areas of the Middle Atlantic seaboard, the 10-foot quads, while usable, leave much to be desired in terms of accuracy - particularly in the crucial areas between the shoreline and the 10-foot contour. In some areas, including large portions of the Upper Chesapeake counties, USGS quads have 20-foot contour intervals; these leave even more to be desired.

In 2002 and 2003 the Maryland Department of Natural Resources developed LIDAR (Airborne Light Detection and Ranging) ground elevations with a two-meter resolution and a very good vertical accuracy for six counties on the Eastern Shore (Worcester, Wicomico, Somerset, Dorchester, Talbot and a portion of Queen Anne's). The Maryland LIDAR data has been used to map SLOSH surges for these counties, resulting in a superior product. Several eastern shore county emergency agencies have noted an excellent correspondence between Isabel flooding and corresponding surge mapping.

The National Hurricane Program must aggressively advocate its needs for better coastal elevation data in conjunction with current efforts to remap flood-prone areas within the NFIP. The advent of more detailed and accurate large-area mapping technologies and techniques such as LIDAR will probably result in higher quality data from future SLOSH basin runs and definitely improve the accuracy of storm tide maps. The map modernization effort currently underway in the NFIP may allow the Hurricane Program to capitalize on work that is already being done for other purposes. If that opportunity is not available for current and future HES regions or efforts, the ICCOH and participating states should investigate other funding options and agencies to improve hazard mapping.

Recommendation: In concert with the current NFIP Map Modernization Program and other improved mapping efforts, improve the base mapping used in the development of SLOSH model basins and storm tide mapping.

5. More coastal areas throughout the U.S. have clearance times that are approaching or exceeding 24 hours, the maximum amount of alert time provided under a Hurricane Warning from the National Hurricane Center (NHC). Certainly this condition exists in the Hampton Roads region of Virginia. Excessive clearance times increase the likelihood that these communities may have to terminate an evacuation before all vehicles have arrived at safe

destinations. The success or failure of stopping an evacuation already underway may have more implications for public safety than the decisions associated with starting one. Evacuation shutdown operations will probably have major implications for regional traffic control, host shelters/refuges of last resort and emergency public information, all of which will be more difficult in the final hours before the arrival of tropical storm force winds**.**

The areas impacted by Hurricane Isabel utilize extensive tunnel and very high profile bridge systems as evacuation routes. Hurricane Isabel visited problems on Norfolk's Midtown Tunnel and to a lesser degree to the Hampton Roads Bridge Tunnel. Additionally, the existence of the Chesapeake Bay Bridge Tunnel, the Monitor-Merrimac Memorial Bridge Tunnel, the James River Bridge; the William Preston Lane Jr. (Chesapeake Bay) Bridge on US 50/301, the Francis Scott Key Bridge, the Baltimore Harbor Tunnel, the Fort McHenry Tunnel and many other long span or high profile bridges will present difficult and unique operational issues during evacuation shutdown procedures.

Recommendation: For communities and regions with 18-hour or greater clearance times, provide decision making criteria in future transportation analyses that state and local governments can use to develop and implement evacuation shutdown procedures.

6. During the Post-Isabel interviews, most local emergency staff indicated that they had received adequate training on HURREVAC, either from Sea Island Software personnel directly, or at the hands of their state Hurricane Program managers. No one lodged any complaints about the general course of training for HURREVAC. Nonetheless, during the surveys it became apparent that a significant number of emergency staff members in communities were not aware of all the functions available in the program. Capabilities such as viewing the Qualitative Precipitation Forecasts, the areas subject to flood advisories, ETIS traffic congestion forecasts (in North Carolina), or decision arcs apparently were not used extensively during the approach of the storm.

   Despite the overwhelmingly favorable assessments regarding the adequacy of HURREVAC training from respondents in all three states, many of the same officials indicated that their staffs experienced relatively high turnover, especially between seasons. Furthermore, the continuous addition of new functions and refinements within the program, coupled with a six-month period where the software is not needed, or used at all, make it difficult to maintain a high level of proficiency. Consequently, some local government operations may have only a limited number of individuals on hand during a hurricane event who have the skills needed to use the program effectively for protective action decision making.

The surveyed states conduct how-to classes in HURREVAC at centralized locations on an annual basis. Furthermore, a comprehensive self-tutorial CD has been developed and made available to emergency management on the HURREVAC website. Nonetheless, based on requests in the post-Isabel surveys and in the interests of maintaining a certain level of proficiency at the local level from season to season, formalized and in-depth training is needed on a much more frequent basis. The NHMPP should strive to ensure that every local government receives formal, on-site, hands-on training in HURREVAC at least once a year.

Recommendation: Develop a more rigorous and organized training program for HURREVAC to ensure that hands-on and operational-use classes are made available to key disaster-related staff in all hurricane-vulnerable communities on at least an annual basis.

7. During the post-Isabel interviews it was apparent that not all local governments had the latest HURREVAC program. During Hurricane Isabel many communities were using very old versions of the software, despite the fact that significant new functions have been added since the beginning of the 2003 season. Currently, there is no established time table for the release of new versions of the HURREVAC program; consequently many local emergency management offices are not aware of, or have not downloaded, the updates and are using old versions of the program in their hurricane analysis and evacuation decision making processes. The issuance of new iterations of HURREVAC on the same dates every year would maximize the number of users that download the latest versions of the program.

   Another means for ensuring that most users have the latest version of HURREVAC is to develop an automatic download function on the ftp site that loads an update directly into the existing software. A push-type update module, while more difficult and complicated to develop and field, would ensure that all users seeking the latest advisory data during an active storm would also receive the most recent version of the program.

Recommendation: Develop a systematic approach to issuing HURREVAC program updates on the same dates every year, or create the capability to automatically feed version upgrades during routine data downloads.

8. Despite very close coordination with their local National Weather Service Offices throughout the event, local emergency managers in Maryland indicated that having near real time access to sea state and wind data over open water may have helped them realize the true magnitude of the storm tides and waves during Hurricane Isabel. Even hourly data from the two C-MAN stations on or near the Chesapeake Bay (Stations TPLM2 and CHLV2) may have provided ample warning for emergency management officials to more proactively notify and extract residents as hazardous conditions escalated.

   According to local emergency management officials, the storm tide phenomenon experienced during Hurricane Isabel in the upper portions of the Chesapeake Bay near Baltimore and Annapolis was unexpected and more serious than anticipated. Despite close coordination between the local emergency management offices and the NWS office, the populations in the immediate coastal areas were not provided sufficient warning and some had to be evacuated from the storm tide at the very last minute. Therefore, having ready access to open water buoy and tidal gauge information in HURREVAC, the program most likely to be used by emergency management to monitor the storm and for decision making, may have provided to officials in those communities the additional information needed to initiate evacuations more proactively.

   Additionally, the Mid-Atlantic States from the coast to the Appalachians have the benefit of IFLOWS, an integrated real-time rain and river gauge network that provides universal access to its data through an internet site. Hurricane Isabel produced prodigious amounts of rain, particularly in the mountains of Virginia and eastern West Virginia. Therefore, the capability to readily acquire rain and river data in HURREVAC would further simplify operations for emergency management staff and consequently improve public safety, especially with respect to inland flooding issues.

Recommendation: Provide local emergency management with the ability to readily access sea buoy, coastal tide gauge and IFLOWS rain and river gauge data, i.e. incorporating a function that automatically collects and displays that data in HURREVAC.

9. ETIS, or the Evacuation Traffic Information System, is a travel demand forecast model specifically designed to predict the cumulative impacts of multiple evacuation decisions on the U.S. regional evacuation road network. Using the transportation analysis data from the HESs, state and local decision makers can use ETIS to anticipate which road segments are likely to have major traffic congestion. With this information, local governments are able to proactively implement measures to better manage traffic operations, host sheltering, public information and emergency communications during an evacuation event. With ETIS data, logistical planners can also determine which roadway segments will circumvent possible evacuation problem areas so that resources can be moved and pre-staged much more expeditiously.

   Even in North Carolina where the ETIS program is fully functional for many counties, the state EMA did not use the program during Hurricane Isabel and local emergency management staff were only vaguely aware of its existence. This fact clearly indicates that, despite the program's functional existence since 2000, an effective training program demonstrating the operational utility of ETIS data does not exist. The annual effort to train emergency management staff on the functions of the ETIS program has not occurred in over two years and there are no current plans to resuscitate the routine for the foreseeable future. No effort has ever been undertaken to explain its operational uses to state and local officials.

   Recommendation: Develop a formal training program for ETIS that details the operational uses of its functions during evacuations, and ensure that the courses are routinely delivered to federal, state and local officials before each hurricane season.

10. State and local EMAs in all three states requested more guidance and direction in all aspects of emergency operations during hurricanes. In addition to the issues described above, local government officials requested assistance in developing hurricane response plans and other operational procedures. They also asked for in-depth courses, training tools and procedural templates to assist them in performing their hurricane planning and preparedness activities.

    These repeated requests for more hurricane training and other statements from state and local officials indicate that hurricane training must generally address more topics, especially where response planning and operations are concerned; be tailored to better address regional variations and conditions; and occur with greater frequency in more communities. Clearly, based on the interviews, the hurricane curriculum for resident EMI courses, field-delivered classes and even independent study modules should be more comprehensive in scope and more aggressively marketed to state and local government officials.

    Recommendation: Expand and re-vamp the entire curriculum for the NHMPP to include more in-depth training on planning, preparedness, mitigation, and response operations (pre- and post- landfall) for hurricanes.

    Among some of the training measures that can be considered for improving the hurricane curriculum:

    a. Restructure the Introduction to Hurricane Preparedness Course (L324) to provide less detail on meteorological and hazard assessment issues and more specific training on emergency management issues;
    b. Revamp the field-delivered Hurricane Planning Course (G360) to make it longer and provide more class participation activities that specifically relate to the development of a hurricane response schedule;
    c. Prepare formal field-delivered classes that relate to the specific operational use and interpretation of data from the various tools in the NHMPP (e.g. SLOSH Display, HURREVAC, ETIS), not just training on how the functions work;
    d. Develop resident, field-delivered or independent study courses that specifically address inland flooding evacuation issues including modules on the NFIP, flood mitigation techniques as well as operational planning and response procedures; and

e. Develop independent study courses that go into greater detail on hurricane planning and response issues such as developing evacuation and sheltering plans; hurricane decision making processes and procedures (not just the meteorology and NHC products); post-landfall hurricane response operations; re-entry and impact assessment procedures; etc.

11. With the reported staff turnover in the local offices surveyed in this post-storm effort, simply providing sporadic hurricane training does not ensure that emergency management personnel will be able to adequately respond to hurricane situations. The NHMPP must develop a curriculum to effectively provide initial training to officials at all levels of government, as well as maintain and update their knowledge base beyond the hurricane season. Furthermore, this continuing education effort must occur with sufficient frequency to ensure that every community continuously has trained staff on hand. Few other hazards require as high of a level of technical expertise in the interpretation and operational use of data as do hurricanes. Few hazards predicate the success of a response operation on the effective application of mitigation and preparation actions before the event. Other than hurricanes, few other hazards place such a burden on emergency management and local officials relative to safeguarding people's lives. A lack of hurricane-related training, which in turn reduces the effectiveness of protective action decision making and execution, can have adverse consequences for public safety in a community.

    Recommendation: Formalize the delivery means for field-based hurricane courses, especially to local officials, to ensure better training coverage and frequency.

    Among the techniques that can be applied in this regard:

    a. Create a cadre of trained federal, state and local officials, as well as consultants to provide training year round to any state or community participating in the NHMPP;
    b. Similar to the Certified Floodplain Managers program, establish a hurricane-related emergency operations certification process for personnel, possibly contingent on proving operational experience during real-events; a succession of required courses and training; demonstrated proficiency is select skill sets; and an exam; and
    c. Develop a state program accreditation process whereby a peer review is conducted using established hurricane-related training and proficiency criteria.

12. Among the specific requests for hurricane response-related training aids from surveyed local governments:

    a. Templates or pre-scripted formats for writing evacuation orders and emergency declarations;
    b. Templates or pre-scripted formats for evacuation, sheltering and other hurricane response-related press releases for use during hurricane events;
    c. A one-page fact sheet on the various hurricane response tools that incorporates a timeline on when to use them;
    d. A generic time delineating schedule for hurricane response operations which can readily be adapted to fit local needs and issues; and
    e. A compendium of best practices used by local governments throughout the country in addressing specific pre- and post-landfall hurricane operational issues.

Recommendation: Develop and distribute more training aids to facilitate hurricane response operations and activities at the state and local level.

Chapter 6
Behavioral Analyses

North Carolina Behavioral Surveys

Sampling - Telephone interviews were conducted with residents of eastern North Carolina in the spring of 2004 concerning their response during Hurricane Isabel. The sample allocation is shown in Table NC-1, and a discussion of sample size reliabilities is included as Appendix B. Residents of Virginia and Maryland were also interviewed as part of the post-Isabel behavioral assessment, but questions differed slightly among states. Some questions were included to assist in future analyses that will be conducted as part of hurricane evacuation studies. The complete questionnaire appears in Appendix C.

Table NC-1. Sample sizes by location

Outer Banks North	Southern Shores and north	201
Outer Banks South	South of Southern Shores	201
Sound (Cat 1-3 Surge areas)	Bertie County Chowan County Perquimans County Pasquotank County	206

Evacuation Participation Rates and Related Factors - Fewer than half the respondents said they left their homes to go someplace safer in Isabel (Table NC-2). Rates were higher on the Outer Banks than in areas bordering the northern shore of Albemarle Sound.

Table NC-2. Evacuation participation rates, by location (percent of respondents)

	Outer Banks North	**Outer Banks South**	**Sound**
Left	42	45	23
Stayed	58	55	77

Reasons for Evacuating or Staying - When asked what factors most influenced their evacuation decisions, most respondents on the Outer Banks cited storm characteristics (forecast track and strength) rather than information they heard from officials or the media (Table NC-3). Among residents along the sound, track, strength, and media information were cited with equal frequency.

Note: Percentages in tables throughout this report do not always sum to 100% due to rounding of individual values.

Table NC-3. Primary reason given for decision to leave or stay, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Track	35	31	21
Strength	36	37	27
Officials	10	9	10
Media	9	12	24

Evacuation Notices from Officials - Most people on the Outer Banks said they heard evacuation notices from officials, but most along the Sound did not (Table NC-4). Of those respondents who said they heard from officials that they should evacuate, a slight majority said the notices were mandatory. Despite responses to the previous question about factors affecting evacuation decision, respondents who said they heard mandatory evacuation notices were more likely than others to evacuate (44% if heard orders, 37% if heard recommendations, 30% if heard neither).

Table NC-4. Official evacuation notices heard, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Yes, heard notices	74	67	30
No, did not hear	22	30	68
Don't know	4	4	2

Evaluation of Information from Officials - The great majority of interviewees said the information provided by officials was useful in making evacuation decisions (Table NC-5), especially on the Outer Banks. When asked how certain officials seemed about the need to evacuate or not, most people said officials were very certain or fairly certain (Table NC-6). Officials were perceived as being more certain on the Outer Banks than along the sound. Most of those interviewed said they had either a great deal or a fair amount of confidence in the ability of officials to decide on the need to evacuate (Table NC-7), again with officials getting higher scores on the Outer Banks. Most respondents said officials call for evacuation about the right amount of times, rather than too often or not often enough (Table NC-8).

Table NC-5. Evaluation of information provided by public officials, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Helpful	83	75	64
Not Helpful	7	10	16
Mixed	4	9	8
Don't Know	7	5	8
Other	1	3	4

Table NC-6. How certain officials seemed regarding the need to evacuate, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Very Certain	59	55	35
Fairly Certain	28	25	28
Not Certain	5	7	13
Varied	1	3	3
Don't Know	8	9	18
Other	1	3	4

Table NC-7. Confidence in ability of officials to decide on the need to evacuate, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Great Deal	54	50	33
Fair Amount	35	34	40
Not Much	5	11	13
None	3	4	4
Don't Know	4	3	9
Other	0	0	1

Table NC-8. Evaluation of how often officials call for evacuation, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Too Often	14	9	5
Not Enough	4	8	9
About Right	77	74	66
Don't Know	5	9	18
Other	0	0	2

Concerns Entering into Decision Making – Approximately one third of people in all three survey locations said they were concerned about attempting to evacuate and being caught in traffic on the road as the hurricane approached (Table NC-9). A majority of those on the Outer Banks also said they were concerned about being able to return home after evacuating.

Table NC-9. Concerned in Isabel about being caught on the road attempting to evacuate, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Yes	38	32	26
No	62	67	73
Don't Know	1	1	1

Table NC-10. Concerned in Isabel about being able to return home after evacuating, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Yes	55	61	33
No	44	38	66
Don't Know	1	1	1

In about a fourth of the surveyed households someone in the household had to work during the Isabel evacuation (Table NC-11). However, in three-fourths of those households, evacuation was not affected (Table NC-12).

Table NC-11. Households with someone required to work during evacuation, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Yes	25	33	20
No	75	67	80

Table NC-12. Effect of work on household's evacuation, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
No Effect	74	72	76
Did Not Evacuate	10	9	10
Part Stayed	8	3	0
Delayed	8	10	2
DK/Other	0	6	12

Preparations to Evacuate - About half the sample on the northern part of the Outer Banks and along the Sound said they would have evacuated if they had been convinced that Isabel was going to strike their location directly (Table NC-13). A third of respondents on the southern portion of the Outer Banks gave that answer. Most people in all three areas said they had made preparations to leave in case the threat worsened sufficiently (Table NC-14).

Table NC-13. Would have evacuated if a direct hit had been anticipated, by location (percent of respondents who did not evacuate)

	Outer Banks North	Outer Banks South	Sound
Yes	53	34	54
No	35	50	32
Don't Know/Other	12	16	13

Table NC-14. Made preparations to evacuate in case threat worsened, by location (percent of respondents who did not evacuate)

	Outer Banks North	Outer Banks South	Sound
Yes	63	64	53
No	34	35	47
Don't Know/Other	4	1	0

Sources of Information - Table NC-15 displays the percentage of interviewees saying they relied a "great deal" on various sources of information about Isabel. The Weather Channel, local television, and local radio were the most heavily used sources. Roughly 10% said they used the Internet a great deal.

Table NC-15. Relied a great deal on source of information, by location (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Local Radio	46	46	51
Local TV	58	50	64
CNN	18	23	13
Weather Channel	75	71	62
Other Cable	19	19	14
Internet	9	13	6
AOL	2	7	3
Friends/Relatives	11	23	19

Perceived Vulnerability - Respondents were reminded how strong Isabel had been at various stages in her existence and asked how the storm would have affected their homes if the strongest part of Isabel had struck their locations with three different intensities. They were asked whether their homes would have flooded dangerously and whether their homes would have been safe to stay in, considering both wind and water, if Isabel had struck them directly with winds of 155 MPH, 125 MPH, and 100 MPH. Results are shown in Tables NC-16 through NC-21. Even in a 155 MPH storm, 20% of the sample indicated that their homes would be safe, and another 10% didn't know whether they would be safe or not. Only half the respondents fear a 125 MPH storm, and just a third are concerned about a storm with 100 MPH winds.

Table NC-16. Believe home would have flooded dangerously if Isabel had struck community directly with 155 MPH winds, by location and risk area (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Would Flood	34	61	62
Wouldn't Flood	58	35	29
Don't Know	9	4	8

Table NC-17. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 155 MPH winds, by location and risk area (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Unsafe	68	71	70
Safe	22	22	20
Don't Know	10	7	9

Table NC-18. Believe home would have flooded dangerously if Isabel had struck community directly with 125 MPH winds, by location and risk area (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Would Flood	64	48	38
Wouldn't Flood	23	43	51
Don't Know	12	8	11

Table NC-19. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 125 MPH winds, by location and risk area (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Unsafe	46	48	59
Safe	40	42	31
Don't Know	14	10	10

Table NC-20. Believe home would have flooded dangerously if Isabel had struck community directly with 100 MPH winds, by location and risk area (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Would Flood	17	31	35
Wouldn't Flood	74	61	55
Don't Know	9	8	10

Table NC-21. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 100 MPH winds, by location and risk area (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
Unsafe	25	31	39
Safe	65	62	53
Don't Know	10	8	8

Confidence in Hurricane Forecasts - Interviewees were asked how accurately the National Hurricane Center forecasts various characteristics of hurricanes 24 hours in advance. It is possible that misconceptions about forecast accuracy could lead to inappropriate responses during storm threats if, for example, undue confidence was placed in the forecast. Respondents were asked the following:

1. What is the average 24-hour landfall location error? (Answer: 50 to 100 miles)
2. What is the average 24-hour landfall timing (i.e., arrival time) error? (Answer: 3 to 6 hours)
3. Are storms more likely to arrive sooner or later than forecast? (Answer: sooner)
4. What is the average 24-hour intensity error? (Answer: approximately 10 MPH)
5. Are storms more likely to be stronger or weaker than forecast? (Answer: weaker)

“Correct” answers were determined from data provided by the National Hurricane Center and data on the NHC website, but do not necessarily reflect the judgments of the National Hurricane Center. All the answers require caveats and assumptions, with attention to nuances about which the public is not usually aware. The goal of the survey was to get a rough indication of public expectations compared to a plausible expression of reality. Answers provided by respondents appear in Tables NC-22 through NC-26. A substantial portion of respondents gave incorrect answers or responded “don’t know” to each question, with errors on both “sides” of the correct response. Subsequent data analyses will attempt to discern the effect of beliefs about forecast accuracy on evacuation decisions.

Table NC-22. Perceived accuracy of 24-hr forecast hurricane landfall location (percent of respondents)

	Outer Banks North	**Outer Banks South**	**Sound**
10 Miles	22	26	31
50 Miles	44	47	37
100 Miles	20	13	15
200 Miles	2	3	2
> 200 Miles	2	2	2
Don’t Know/Depends	11	9	14

Table NC-23. Perceived accuracy of 24-hr forecast hurricane landfall timing (percent of respondents)

	Outer Banks North	**Outer Banks South**	**Sound**
.5 hr	13	15	25
1 hr	22	20	20
3 hrs	26	32	25
6 hrs	18	13	8
12 hrs	8	7	4
18 hrs	2	3	4
> 18 hrs	1	0	1
Don’t Know/Depends	12	11	13

Table NC-24. Perceived bias in accuracy of 24-hr forecast hurricane landfall timing (percent of respondents)

Landfall is:	Outer Banks North	Outer Banks South	Sound
Sooner than forecast	8	9	13
Later than forecast	27	25	27
Neither	52	58	46
Don't Know/Depends	14	8	14

Table NC-25. Perceived accuracy of 24-hr forecast hurricane intensity (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
2 MPH	4	10	11
5 MPH	11	10	15
10 MPH	23	23	23
20 MPH	30	29	19
50 MPH	8	8	6
> 50 MPH	5	4	5
Don't Know/Depends	20	17	21

Table NC-26. Perceived bias in 24-hr forecast hurricane intensity (percent of respondents)

Intensity Is:	Outer Banks North	Outer Banks South	Sound
Stronger than Forecast	9	10	15
Weaker than Forecast	32	27	22
Neither	46	54	49
Don't Know/Depends	13	9	14

Respondents were also asked how well the National Hurricane Center did in forecasting hurricanes, compared to the respondent's favorite television weathercaster. About half said the Hurricane Center did a better job, and fewer than 5 percent said the Hurricane Center did less well than the television weathercaster (Table NC-27).

Table NC-27. Perceived accuracy of National Hurricane Center vs. favorite television weathercaster (percent of respondents)

	Outer Banks North	Outer Banks South	Sound
NHC Better	55	56	48
NHC Worse	4	1	3
Same	35	39	45
Don't Know/Depends	7	5	4

Other Evacuation Behaviors

Type of Refuge - None of the surveyed evacuees from the Outer Banks said they went to public shelters, and only 9% of the evacuees from counties bordering the Sound said they used public shelters (Table NC-28). Most people, as in most evacuations, went to the homes of friends and relatives. Evacuees from the Outer Banks were more likely than those from the mainland to go to hotels and motels.

Table NC-28. Type of refuge used in Isabel (percent of respondents who evacuated)

	Outer Banks North	Outer Banks South	Sound
Public Shelter	0	0	9
Church	0	1	4
Friend/Relative	59	60	75
Hotel/Motel	22	26	9
Workplace	2	0	2
Other	16	13	2

Location of Refuge - Evacuees from counties on the Sound tended to stay in their own county, and almost half said they went someplace in their own neighborhood (Table NC-29). A minority of evacuees from the Outer Banks went into Virginia or other states.

Table NC-29. Location of refuge used in Isabel (percent of respondents who evacuated)

	Outer Banks North	Outer Banks South	Sound
Neighborhood	7	16	45
Own County	14	11	18
North Carolina	26	36	27
Virginia	36	23	8
Maryland	5	2	4
Pennsylvania	3	2	0
DC	1	5	0
Other	8	5	0

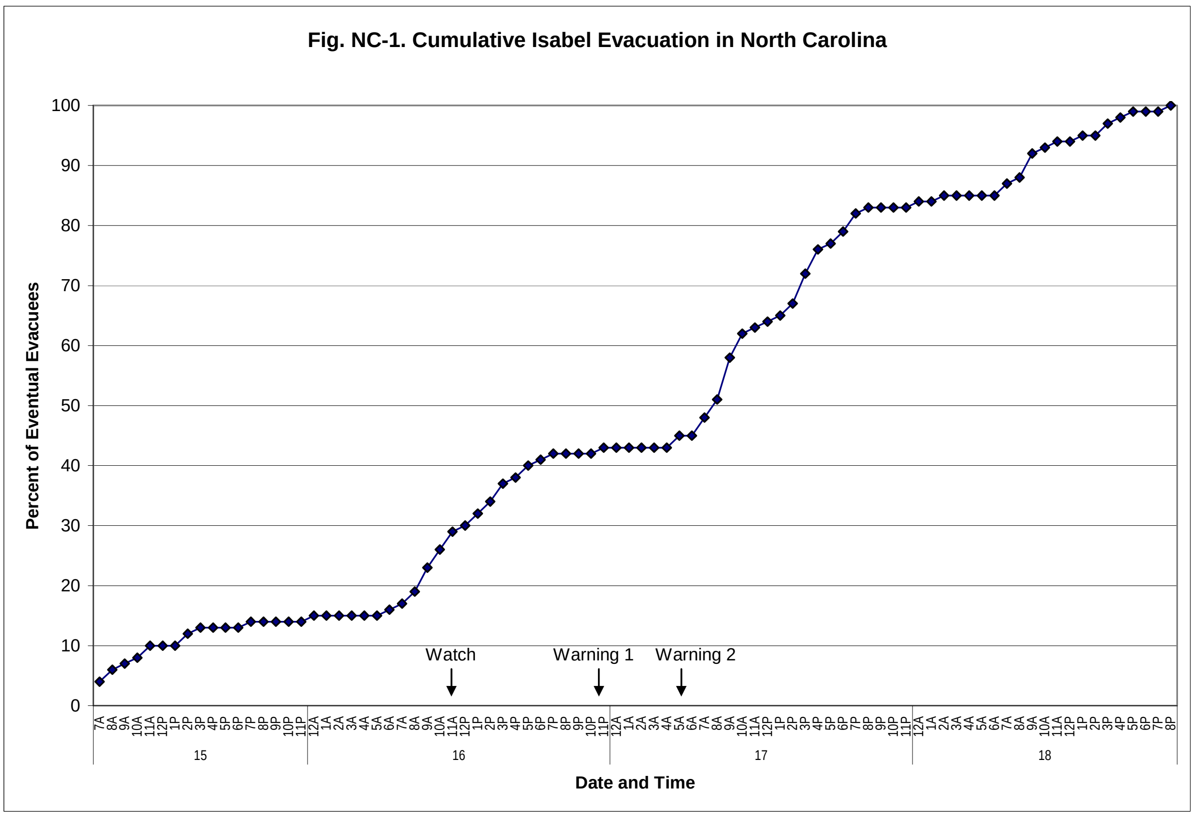
Evacuation Timing - Landfall occurred in North Carolina around 1 PM on Thursday, September 18th. Interviewees were reminded on that timing as well as when watches and warnings were posted and asked when they left their homes. Evacuation appears to have begun earlier in the southern part of the Outer Banks than in the northern portion, and departures from areas on the

Sound were later than from the Outer Banks (Table NC-30). Timing of the overall response is shown in Figure NC-1.

Table NC-30. Date of departure (percent of respondents who evacuated)

	Outer Banks North	Outer Banks South	Sound
Sep. 15th	13	17	9
Sep. 16th	29	41	7
Sep. 17th	47	30	55
Sep. 18th	12	12	30

Figure NC-1. Cumulative Isabel Evacuation in North Carolina



Vehicle Use - Of all the vehicles available for households to use in the evacuation, between 60% and 70% were taken (Table NC-31). The average number of vehicles per household was higher on the Outer Banks than along the Sound. Fewer than 5% of the evacuating households took RVs or motor homes or pulled trailers or boats.

Table NC-31. Vehicle use in Isabel

	Outer Banks North	**Outer Banks South**	**Sound**
% of Available	59	70	61
No. per Household	1.10	1.21	1.02
% w/ RVs, Trailers	2	3	4

Households Requiring Assistance - On the Outer Banks only one to two percent of the households had members requiring assistance in order to evacuate or shelter (Table NC-32). The figure was higher among households evacuating along the sound, but that estimate is less statistically reliable due to the lower number of evacuees from that area (48 out of 200). Of those households needing assistance, needs were evenly divided among those requiring transportation and those needing special attention in a shelter.

Table NC-32. Household required evacuation assistance in Isabel (percent of households that evacuated)

Outer Banks North	**Outer Banks South**	**Sound**
1	2	8

Virginia Behavioral Surveys

Sampling - Telephone interviews were conducted with Virginia in the spring of 2004 concerning their response during hurricane Isabel. The sample was allocated among five geographical areas of the state and three storm surge risk zones, as shown in Table VA-1. Storm surge risk areas in most of the study area were ascertained from a variety of maps provided by the Norfolk office of the U.S. Army Corps of Engineers. In the more urbanized locations current SLOSH or Hurricane Evacuation Zone maps were employed. In the less populated areas a combination of FIRMs from the National Flood Insurance Program, older SLOSH maps, SLOSH elevation data, and topographic maps were used to estimate inundation areas. Interviews on the Eastern Shore were distributed through the category 1 through 4 surge zones, using a listing of streets in each zone provided by the Philadelphia District of the Corps of Engineers. A discussion of statistical reliability of estimates derived from samples of various sizes is included in Appendix I. The complete questionnaire used in the survey appears in Appendix II.

Table VA-1. Sample sizes by hurricane risk area and location

	Norfolk	**Hampton**	**Surry**	**N Neck**	**E Shore***
Cat 1-2 (1-4)*	100	100	100	100	100
Cat 3-4	200	200	0	100	0
Non-surge	100	100	0	100	0

Norfolk	Norfolk, Virginia Beach, Portsmouth, Chesapeake, Suffolk
Hampton	Hampton, Newport News, Poquoson, York County
Surry	Surry County, Isle of Wight County
Northern Neck	Westmoreland through Gloucester Counties on Chesapeake Bay
Eastern Shore	Northampton County, Accomack County

*Category 1-4 surge areas used on the Eastern Shore

Note: Percentages in tables throughout this report do not always sum to 100% due to rounding of individual values.

Evacuation Participation Rate and Related Factors - Fewer than half the respondents in any of the five locations said they left their homes to go someplace safer in Isabel (Table VA-2). The highest participation rate was in the category 1 and 2 surge zones of the Northern Neck counties, where 41% evacuated.

Table VA-2. Evacuation participation rates, by location (percent of respondents)

	Norfolk	**Hampton**	**Surry**	**N Neck**	**E Shore**
Cat 1-2 (1-4)	22	31	9	41	30
Cat 3-4	14	23	NA	25	NA
Non-surge	19	19	NA	23	NA

Explanations of Evacuation Decisions - Interviewees were asked whether their decisions to evacuate or not were influenced primarily by forecast track and strength of the storm, information they heard from officials, or information they heard from media sources. Replies were fairly evenly divided among storm characteristics and media information, with information from officials mentioned less frequently (Table VA-3).

Table VA-3. Primary reason given for decision to leave or stay, by location (percent of respondents)

	Norfolk	**Hampton**	**Surry**	**N Neck**	**E Shore**
Track	27	23	25	23	37
Strength	27	28	34	25	30
Officials	12	13	8	10	8
Media	24	24	24	21	16
Don't Know	4	4	3	7	6

Evacuation Notices from Officials - Most participants in the survey said they didn't hear any sort of evacuation notice from public officials in their location (Table VA-4). However, despite the lack of influence attributed to officials in the previous question, *there was significant variation in evacuation rates depending on whether respondents heard official evacuation notices or not.* Among those who said they heard mandatory evacuation orders, 61% evacuated, compared to 39% who heard recommendations that they leave, and 18% who heard neither. Hearing evacuation notices from officials was related to evacuation within all risk zones.

Table VA-4. Official evacuation notices heard, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	25	35	7	23	25
Cat 3-4	15	20	NA	19	NA
Non-surge	9	12	NA	20	NA

Evaluation of Information from Officials - In all locations except Surry and Isle of Wight counties, a strong majority in the sample said the sort of information they received from officials was very helpful in deciding whether to evacuate (Table VA-5). Most people who expressed an opinion said that officials seemed either very certain or fairly certain of the need to evacuate or not (Table VA-6). In all five locations respondents said they had a great deal or a fair amount of confidence in the ability of officials to decide on the necessity of evacuation (Table VA-7). Most people said their officials call for evacuation about the right amount of times, rather than too often or not often enough (Table VA-8).

Table VA-5. Evaluation of information provided by public officials, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Helpful	76	69	42	54	65
Not Helpful	11	17	31	18	14
Mixed	5	7	3	9	6
Don't Know	8	7	19	15	14
Other	< 1	1	5	4	1

Table VA-6. How certain officials seemed regarding the need to evacuate, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Very Certain	36	40	17	33	29
Fairly Certain	34	25	26	21	32
Not Certain	14	17	23	14	19
Varied	2	3	1	3	0
Don't Know	14	13	28	24	20
Other	1	2	5	6	1

Table VA-7. Confidence in ability of officials to decide on the need to evacuate, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Great Deal	37	39	24	33	37
Fair Amount	46	42	38	39	48
Not Much	12	10	15	11	3
None	2	5	11	5	4
Don't Know	3	4	12	11	8
Other	0	< 1	0	1	1

Table VA-8. Evaluation of how often officials call for evacuation , by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Too Often	9	8	4	5	8
Not Enough	6	8	13	10	6
About Right	74	71	53	58	81
Don't Know	10	13	28	26	5
Other	1	< 1	2	1	0

Concerns in Making Evacuation Decisions - Almost half the respondents in the Norfolk and Hampton areas said they had concerns about attempting to evacuate and being trapped on roadways as the storm arrived (Table VA-9). In the less populous locations, fewer expressed that concern. Of those who said they had that concern, 18% evacuated, compared to 27% who did not have that concern. Approximately a third of those interviewed in each location said they had concerns about being able to return home after evacuating (Table VA-10).

Table VA-9. Concerned in Isabel about being caught on the road attempting to evacuate, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Yes	42	41	27	21	18
No	55	57	70	77	82
Don't Know	4	2	3	2	0

Table VA-10. Concerned in Isabel about being able to return home after evacuating, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Yes	36	31	27	33	33
No	60	66	67	65	64
Don't Know	3	3	6	2	3

Effect of Work on Evacuation Decisions - About 20% of those surveyed indicated that someone in the household had to work during the Isabel evacuation (Table VA-11). However, very few respondents stated that evacuation decisions by the household were affected adversely (Table VA-12).

Table VA-11. Households with someone required to work during evacuation, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Yes	22	23	20	22	12
No	78	77	80	78	87
Don't Know	0	1	0	1	1

Table VA-12. Effect of work on household's evacuation, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
None	73	68	75	85	92
Stayed	10	14	10	8	0
Part Stayed	9	10	0	0	8
Delayed	6	8	15	5	0
Don't Know	1	0	0	2	0

Preparations to Evacuate - In all but one area most people who did not evacuate said they would have left if it had appeared that Isabel was going to strike their location directly (Table VA-13). Most also indicated that they had made preparations to evacuate in case the threat situation worsened sufficiently (Table VA-14).

Table VA-13. Would have evacuated if direct hit had been anticipated, by location (percent of respondents who did not evacuate)

	Norfolk	Hampton	Surry	N Neck	E Shore
Yes	57	63	55	46	68
No	29	28	35	41	27
Don't Know	14	10	10	13	5

Table VA-14. Made preparations to evacuate in case threat worsened, by location (percent of respondents who did not evacuate)

	Norfolk	Hampton	Surry	N Neck	E Shore
Yes	57	60	57	51	76
No	41	39	43	47	21
Don't Know	2	1	0	2	3

Sources of Information - Participants in the survey were presented with a list of sources from which they might have received information about Isabel and asked how much they relied upon each. The Percentage of respondents saying they relied a "great deal" on sources is shown in Table VA-15. Local television stations were relied upon most, followed by local radio and the Weather Channel. Just 5% to 11% said they relied on the Internet a great deal.

Table VA-15. Relied a great deal on source of information, by location (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Local Radio	49	53	40	53	47
Local TV	74	77	65	60	66
CNN	13	14	9	13	9
Weather Ch	46	52	34	40	49
Other Cable	14	17	13	12	16
Internet	6	7	5	11	11
AOL	3	4	4	6	2
Friends	8	13	11	16	8

Perceived Vulnerability - Respondents were reminded how strong Isabel had been at various stages in her existence and asked how the storm would have affected their homes if the strongest part of Isabel had struck their locations with three different intensities. They were asked whether their homes would have flooded dangerously and whether their homes would have been safe to stay in, considering both wind and water, if Isabel had struck them directly with winds of 155 MPH, 125 MPH, and 100 MPH. Results are shown in Tables VA-16 through VA-21.

Perception of risk from flooding is greatest in the Norfolk, Hampton, and Northern Neck areas, but even in those locations a substantial number of people in category 1 and 2 surge areas believe they would not flood dangerously in a storm with 155 MPH winds and the percentage increases with storms of 125 MPH and 100 MPH. In Surry and Isle of Wight counties, elevation rises rapidly away from many water bodies, and the sampling methods used to estimate surge-vulnerable households might erroneously have included households outside of surge-prone areas. Although few in the Surry and Isle of Wight samples fear flooding, they are as concerned as any location when asked to consider both wind and water.

Perceived vulnerability was an important factor associated with evacuation. Among those respondents who said their homes would not be safe in a 125 MPH hurricane, for example, 32% evacuated in Isabel. Among those who said their homes would be safe, only 12% left.

Table VA-16. Believe home would have flooded dangerously if Isabel had struck community directly with 155 MPH winds, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	69	75	27	57	48
Cat 3-4	41	51	N/A	46	N/A
Non-surge	23	43	N/A	23	N/A

Table VA-17. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 155 MPH winds, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	77	73	73	76	68
Cat 3-4	66	70	NA	62	NA
Non-surge	57	68	NA	57	NA

Table VA-18. Believe home would have flooded dangerously if Isabel had struck community directly with 125 MPH winds, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	55	65	17	52	34
Cat 3-4	27	37	NA	37	NA
Non-surge	19	32	NA	15	NA

Table VA-19. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 125 MPH winds, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	59	64	57	69	52
Cat 3-4	49	54	NA	56	NA
Non-surge	47	56	NA	44	NA

Table VA-20. Believe home would have flooded dangerously if Isabel had struck community directly with 100 MPH winds, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	31	45	17	42	22
Cat 3-4	16	22	NA	24	NA
Non-surge	16	19	NA	12	NA

Table VA-21. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 100 MPH winds, by location and risk area (percent of respondents)

	Norfolk	Hampton	Surry	N Neck	E Shore
Cat 1-2 (1-4)	28	43	34	52	37
Cat 3-4	30	34	NA	35	NA
Non-surge	33	44	NA	32	NA

Type of Refuge - Very few of the evacuees said they went to public shelters (Table VA-22). The highest incidence was in the Northern Neck area where 11% went to shelters. Most evacuees went to the homes of friends and relatives, followed in most locations by hotels and motels. There were too few evacuees from Surry and Isle of Wight counties to estimate evacuation behaviors.

Table VA-22. Type of refuge used in Isabel (percent of respondents who evacuated)

	Norfolk	Hampton	Surry	N Neck	E Shore
Public Shelter	4	3	NA	11	3
Church	1	1	NA	1	0
Friend/Relative	68	59	NA	68	57
Hotel/Motel	21	32	NA	11	33
Workplace	1	3	NA	2	3
Other	4	2	NA	7	3

Location of Refuge - Evacuees from the Norfolk and Hampton areas were more likely than others to leave their own locality (Table VA-23). Most people evacuating in the Northern Neck area went to destinations in their own neighborhood or community. Almost a fourth of the Eastern Shore evacuees went into Maryland.

Table VA-23. Location of refuge used in Isabel (percent of respondents who evacuated)

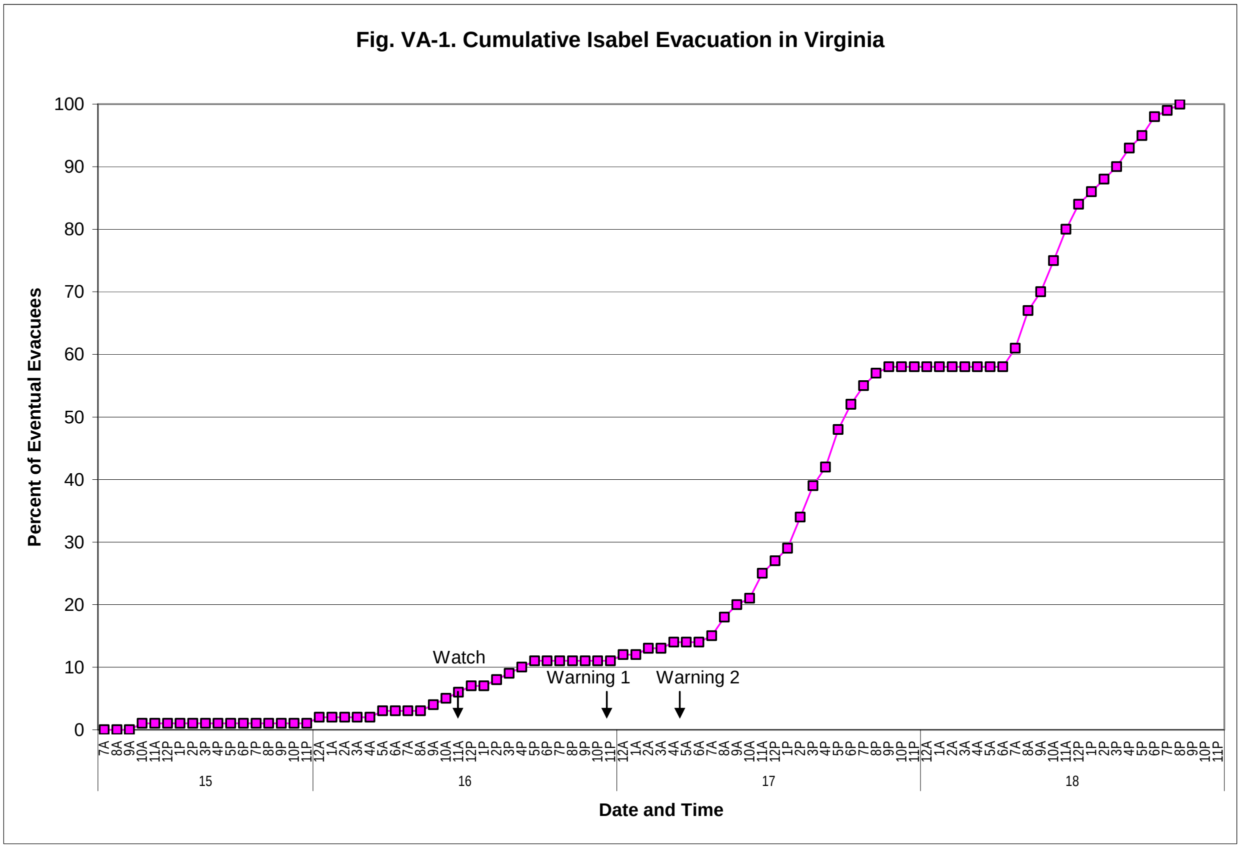
	Norfolk	Hampton	Surry	N Neck	E Shore
Neighborhood	14	11	NA	41	23
Own Locality	26	23	NA	25	23
Virginia	42	58	NA	32	16
North Carolina	4	2	NA	1	3
Maryland	4	1	NA	1	23
Pennsylvania	0	1	NA	0	3
DC	1	0	NA	0	0
Other	8	4	NA	0	10

Evacuation Timing - Isabel made landfall in North Carolina around 1 PM on Thursday, September 18th. Interviewees were reminded of that timing as well as the times when watches and warnings were posted and asked when they left their homes. Evacuation appears to have started slightly earlier in the Norfolk area, compared to other Virginia locations (Table VA-24). Most Northern Neck evacuees left on the 18th. Overall response timing is shown in Figure VA-1.

Table VA-24. Date of departure (percent of respondents who evacuated)

	Norfolk	Hampton	Surry	N Neck	E Shore
Sep. 15th	3	11	NA	1	4
Sep. 16th	11	11	NA	7	15
Sep. 17th	60	47	NA	37	46
Sep. 18th	26	41	NA	55	35

Figure VA-1. Cumulative Isabel Evacuation in Virginia



<u>Vehicle Use</u> - Evacuating households were asked how many vehicles were available that could have been used in the evacuation, and how many were actually used. Between 53% and 63% of the available vehicles were used (Table VA-25). Number of vehicles per evacuating household was highest in the Hampton area. Fewer than 5% of the households took RVs or motor homes or pulled trailers or boats.

Table VA-25. Vehicle Use in Isabel

	Norfolk	**Hampton**	**Surry**	**N Neck**	**E Shore**
% of Available Vehicles	53	63	NA	59	63
Vehicles per Household	.91	1.26	NA	1.19	1.23
RVs, Trailers	1	4	NA	3	3

Households Needing Assistance - Five percent or fewer of the respondents in evacuating households said that anyone in the home required assistance in evacuating (Table VA-26). The needed assistance was roughly equally divided between people needing transportation and people need special care in a shelter or elsewhere.

Table VA-26. Household required evacuation assistance in Isabel (percent of households that evacuated)

Norfolk	Hampton	Surry	N Neck	E Shore
5	1	NA	4	0

Maryland Behavioral Surveys

Sampling - Telephone interviews were conducted with Maryland residents in the spring of 2004 concerning their response during hurricane Isabel. The Baltimore District of the Corps of Engineers provided listings of streets in each surge inundation area on the western shore of Chesapeake Bay. The Philadelphia District provided that information for the Eastern Shore. The sample was allocated among five areas of the state and three storm surge inundation areas as shown in Table MD-1. On the Eastern Shore interviews were conducted throughout the category 1-4 surge zones. An attempt was made to interview residents in surge-prone areas of Montgomery and Prince George's Counties, but there were too few respondents contacted successfully to make separate analyses in those areas valid. A discussion of statistical reliability of estimates derived from samples of various sizes is included in Appendix I. The complete questionnaire used in the survey appears in Appendix II.

Table MD-1. Sample sizes by hurricane risk area and location

	S. Shore	A. Arundel	DC	Baltimore	E Shore*
Cat 1 (1-4)*	129	129	13	159	104
Cat 2-4	129	127	4	150	0
Non-surge	105	101	185	110	0

S. Shore	Charles County St. Mary's County Calvert County
A. Arundel	Anne Arundel County, south of Severna Park
DC	Montgomery County Prince George's County
Baltimore	Anne Arundel County, Severna Park and north Baltimore County Baltimore City Carroll County Howard County
E Shore	Dorchester County Talbot County Queen Anne's County Somerset County

*Category 1-4 surge zone used on Eastern Shore

Note: Percentages in tables throughout this report do not always sum to 100% due to rounding of individual values.

Evacuation Participation Rates and Related Factors - Evacuation rates were low throughout the Maryland coast (Table MD-2). The highest rate was in the southernmost counties on the western shore.

Table MD-2. Evacuation participation rates, by location (percent of respondents)

	S. Shore	**A. Arundel**	**DC**	**Baltimore**	**E Shore**
Cat 1 (1-4)	32	9	NA	18	5
Cat 2-4	16	13	NA	15	NA
Non-surge	13	6	4	6	NA

Explanations of Evacuation Decisions - Interviewees were asked whether their decisions to evacuate or not were influenced primarily by forecast track and strength of the storm, information they heard from officials, or information they heard from media sources. Along the south shore, in Anne Arundel, and on the Eastern Shore, the most prevalent reason cited was the forecast track of the storm (Table MD-3). In the DC and Baltimore areas responses were more evenly distributed among storm track and strength and media information. Information from officials was mentioned least frequently.

Table MD-3. Primary reason given for decision to leave or stay, by location (percent of respondents)

	S. Shore	**A. Arundel**	**DC**	**Baltimore**	**E Shore**
Track	41	42	29	27	43
Strength	23	21	23	20	23
Officials	12	11	13	11	9
Media	15	19	29	22	18
DK/Other	10	8	6	21	7

Evacuation Notices from Officials - Few respondents said they heard from officials that they were supposed to evacuate, even in category 1 and 2 surge areas (Table MD-4). The highest incidence was along the south shore where 30% said they heard evacuation notices from officials. However, despite the lack of influence attributed to officials in the previous question, *there was significant variation in evacuation rates depending on whether respondents heard official evacuation notices or not.* Among those who said they heard mandatory evacuation orders, 62% evacuated, compared to 21% who heard recommendations that they leave, and 9% who heard neither.

Table MD-4. Official evacuation notices heard, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	30	10	NA	21	10
Cat 2-4	16	17	NA	28	NA
Non-surge	12	7	1	10	NA

Evaluation of Information from Officials - In all of the survey locations a majority of those interviewed said the information provided by officials was helpful in deciding whether to evacuate (Table MD-5). Approximately half the respondents said that officials seemed very certain or fairly certain about the need to evacuate or not, and only 12% to 25% said officials seemed uncertain (Table MD-6). A strong majority in all areas said they had a great deal or fair amount of confidence in the ability of officials to decide whether evacuation was needed (Table MD-7). Over 60% said that officials call for evacuation about the right amount of time (Table MD-8).

Table MD-5. Evaluation of information provided by public officials, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Helpful	56	55	59	52	55
Not Helpful	21	18	14	28	17
Mixed	8	11	10	8	8
Don't Know	12	14	11	10	19
Other	2	2	6	3	1

Table MD-6. How certain officials seemed regarding the need to evacuate, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Very Certain	33	22	26	25	19
Fairly Certain	23	24	26	25	29
Not Certain	15	19	12	25	18
Varied	4	4	2	4	3
Don't Know	23	28	28	17	27
Other	2	3	7	4	4

Table MD-7. Confidence in ability of officials to decide on the need to evacuate, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Great Deal	30	29	28	29	38
Fair Amount	47	47	51	43	31
Not Much	12	14	14	17	20
None	5	5	2	7	4
Don't Know	6	5	5	4	7
Other	1	1	1	0	0

Table MD-8. Evaluation of how often officials call for evacuation, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Too Often	6	5	6	8	4
Not Enough	11	6	6	12	4
About Right	68	65	61	63	66
Don't Know	15	22	23	16	26
Other	1	2	4	1	0

Concerns in Making Evacuation Decisions - Between 20% and 33% of those surveyed said they had concerns about being caught on roadways while trying to evacuate as the storm arrived (Table MD-9). Similar numbers of people said they were concerned about being able to return to their homes if they evacuated (Table MD-10).

Table MD-9. Concerned in Isabel about being caught on the road attempting to evacuate, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Yes	25	28	33	22	20
No	73	71	65	75	79
Don't Know	2	1	1	2	1

Table MD-10. Concerned in Isabel about being able to return home after evacuating, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Yes	37	32	21	34	25
No	59	65	75	62	71
Don't Know	4	3	5	4	4

Effect of Work on Evacuation Decisions - A minority of respondents (23% to 39%) said someone in the household was required to work during the Isabel evacuation (Table MD-11). However, few of those households indicated that evacuation decisions were affected adversely by someone having to work (Table MD-12).

Table MD-11. Households with someone required to work during evacuation, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Yes	30	22	39	23	29
No	69	75	60	76	70
Don't Know	1	2	1	1	1

Table MD-12. Effect of work on household's evacuation, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
None	88	86	90	88	83
Stayed	2	4	4	7	10
Part Stayed	0	0	0	1	0
Delayed	7	5	3	3	0
Don't Know/Other	3	6	4	5	7

Preparations to Evacuate - More than half of the interviewees who did not evacuate said they would have been willing to leave if they had been convinced that Isabel was going to strike their location directly (Table MD-13). In all locations except DC a majority said they had made preparations to evacuate in case the threat situation worsened (Table MD-14).

Table MD-13. Would have evacuated if a direct hit had been anticipated, by location (percent of respondents who did not evacuate)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Yes	65	64	52	66	54
No	23	22	26	23	30
Don't Know	12	14	23	12	16

Table MD-14. Made preparations to evacuate in case threat worsened, by location (percent of respondents who did not evacuate)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Yes	61	53	36	50	67
No	37	46	62	49	30
Don't Know	2	2	3	1	3

Sources of Information - Participants in the survey were presented with a list of sources from which they might have received information about Isabel and asked how much they relied upon each. Percentage of respondents saying they relied a "great deal" on sources is shown in Table MD-15. In all survey locations local television stations were relied upon the most, followed by either the Weather Channel or local radio. Only 5% to 12% said they relied on the Internet a great deal.

Table MD-15. Relied a great deal on source of information, by location (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Local Radio	33	36	41	30	34
Local TV	60	64	61	66	62
CNN	10	14	6	14	12
Weather Ch	46	50	32	43	48
Other Cable	17	15	9	19	14
Internet	8	12	9	5	9
AOL	4	5	5	2	2
Friends	14	15	7	13	14

Perceived Vulnerability - Respondents were reminded how strong Isabel had been at various stages in its existence and asked how the storm would have affected their homes if the strongest part of Isabel had struck their locations with three different intensities. They were asked whether their homes would have flooded dangerously and whether their homes would have been safe to stay in, considering both wind and water, if Isabel had struck them directly with winds of 155 MPH, 125 MPH, and 100 MPH. Results are shown in Tables MD-16 through MD-21.

A clear majority in surge areas believes their homes would be vulnerable to flooding in storms having winds of 155 MPH or 125 MPH, and believe it would be unsafe to stay in their homes considering both wind and water. Baltimore residents were more likely than others to perceive flooding to be a hazard. In some locations people living in category 2-4 surge zones are as likely as people living in category 1 zones to say they were vulnerable.

Table MD-16. Believe home would have flooded dangerously if Isabel had struck community directly with 155 MPH winds, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	60	69	NA	72	63
Cat 2-4	61	73	NA	78	NA
Non-surge	40	45	21	57	NA

Table MD-17. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 155 MPH winds, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	71	81	NA	77	65
Cat 2-4	77	79	NA	75	NA
Non-surge	59	65	59	57	NA

Table MD-18. Believe home would have flooded dangerously if Isabel had struck community directly with 125 MPH winds, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	55	62	NA	68	51
Cat 2-4	49	64	NA	70	NA
Non-surge	36	37	19	50	NA

Table MD-19. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 125 MPH winds, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	71	70	NA	68	59
Cat 2-4	63	68	NA	63	NA
Non-surge	51	60	51	51	NA

Table MD-20. Believe home would have flooded dangerously if Isabel had struck community directly with 100 MPH winds, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	45	42	NA	58	37
Cat 2-4	33	44	NA	56	NA
Non-surge	26	28	14	35	NA

Table MD-21. Believe home would have been unsafe, considering both wind and water, if Isabel had struck community directly with 100 MPH winds, by location and risk area (percent of respondents)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Cat 1 (1-4)	54	50	NA	55	49
Cat 2-4	44	52	NA	52	NA
Non-surge	40	40	41	39	NA

Type of Refuge - Very few evacuees said they sought refuge in public shelters (Table MD-22). In Baltimore the figure was 8% and in other areas it was just 3%. Most evacuees in all locations went to the homes of friends and relatives. (There were too few evacuees from the DC and Eastern Shore samples to report data on evacuation behaviors.)

Table MD-22. Type of refuge used in Isabel (percent of respondents who evacuated)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Public Shelter	3	3	NA	8	NA
Church	0	0	NA	0	NA
Friend/Relative	79	74	NA	77	NA
Hotel/Motel	13	11	NA	3	NA
Workplace	0	0	NA	2	NA
Other	5	11	NA	9	NA

Location of Refuge - Most evacuees did not go far from home (Table MD-23). Two-thirds to three-fourths went to destinations in their own neighborhood or county.

Table MD-23. Location of refuge used in Isabel (percent of respondents who evacuated)

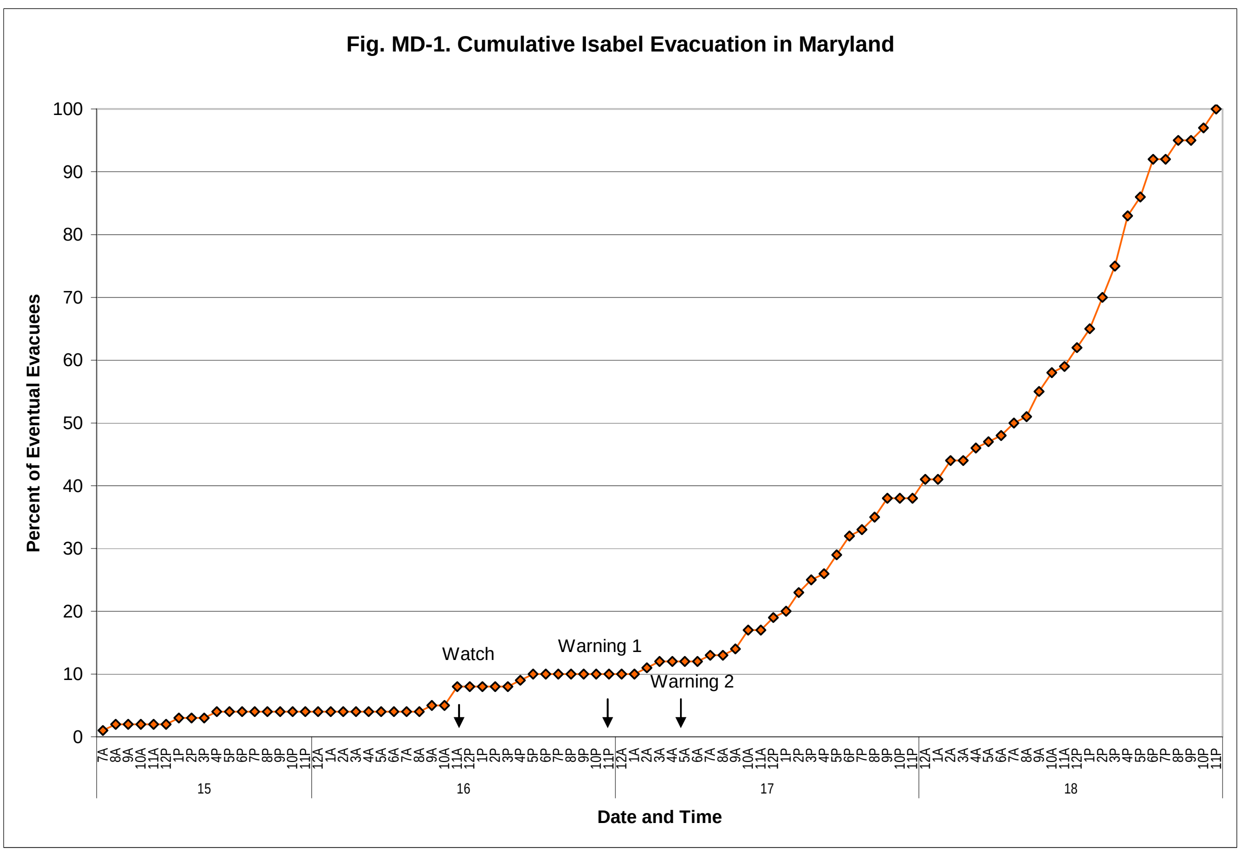
	S. Shore	A. Arundel	DC	Baltimore	E Shore
Neighborhood	22	40	NA	35	NA
County	46	34	NA	44	NA
Maryland	20	20	NA	20	NA
Virginia	11	0	NA	0	NA
Other	1	6	NA	0	NA

Evacuation Timing - Isabel made landfall in North Carolina around 1 PM on Thursday, September 18th. Interviewees were reminded of that timing as well as the times when watches and warnings were posted and asked when they left their homes. Along the south shore and in Anne Arundel, most of the evacuation took place on the 17th and 18th. But in Baltimore most of it occurred on the 18th and 19th, presumably in response to flooding as it occurred.

Table MD-24. Date of departure (percent of respondents who evacuated)

	S. Shore	A. Arundel	DC	Baltimore	E Shore
Sep. 15th	4	0	NA	0	NA
Sep. 16th	6	10	NA	3	NA
Sep. 17th	34	26	NA	12	NA
Sep. 18th	54	61	NA	45	NA
Sep. 19th	0	3	NA	34	NA
Sep. 20th	1	0	NA	5	NA

Figure MD-1. Cumulative Isabel Evacuation in Maryland



Vehicle Use - Evacuating households were asked how many vehicles were available that could have been used in the evacuation, and how many were actually used. Between 55% and 69% of the available vehicles were used (Table VA-25). Number of vehicles per evacuating household was highest in the South Shore area and lowest in Baltimore. In Baltimore 9% of the households took RVs or motor homes or pulled trailers or boats, a considerably higher figure than in other areas.

Table MD-25. Vehicle use in Isabel

	S. Shore	A. Arundel	DC	Baltimore	E Shore
% of Available Vehicles	69	59	NA	55	NA
Vehicles per Household	1.17	1.03	NA	.85	NA
RVs, Trailers	3	0	NA	9	NA

Households Needing Assistance - In the south shore area only one percent of the respondents in evacuating households said that anyone in the home required assistance in evacuating (Table VA-26). The figure was higher in the Anne Arundel (6%) and Baltimore (9%) areas. Transportation was the need cited by almost all respondents, and in about half the cases the assistance was provided by a family member.

Table MD-26. Household required evacuation assistance in Isabel (percent of households that evacuated)

S. Shore	A. Arundel	DC	Baltimore	E Shore
1	6	NA	13	NA

Chapter 7
Transportation and Evacuation

The primary objective of the FEMA / USACE comprehensive hurricane evacuation studies (HES) is the calculation of clearance times. They are the amount of time needed to clear the entire evacuation road network of all evacuation traffic and convey those vehicles and their occupants to a point of relative safety. Usually specified in terms of scenarios based on hurricane intensity groupings, tourist occupancy rates and response timing, clearance times provide emergency managers with the lead time needed before the forecast arrival of tropical storm-force winds to ensure that all evacuees are allowed to reach a safe destination. Clearance times also include travel time and the time waiting in traffic congestion.

The transportation analysis combines variables from the vulnerability analysis (evacuation zones, vulnerable population and evacuating vehicles); behavioral analysis (response rates, participation percentages, intended destinations per evacuation zone); and shelter analysis (shelter use percentages and locations) into a hurricane evacuation transportation model. This transportation model emulates the characteristics of the evacuation roadway network during various hurricane evacuation scenarios to determine the most congested segments and locations, as well as the clearance times needed for protective action decision making.

A recent Transportation Analysis was completed for North Carolina by September 2001 and included in the December 2002 Technical Data Report (TDR) of the Hurricane Evacuation (HES) Restudy. In that effort clearance times were calculated for Beaufort, Bertie, Brunswick, Camden, Carteret, Chowan, Craven, Currituck, Dare, Hyde, Jones, Martin, New Hanover, Onslow, Pamlico, Pasquotank, Pender, Perquimans, Tyrell and Washington Counties. The last HES performed for Virginia was in 1992 and Maryland in 1990.

Table 7-2 provides the observations of local and state government representatives regarding evacuation and transportation related issues during Hurricane Isabel. Transportation and clearance time issues discussed by the study teams with local and state officials for the Hurricane Isabel event included the following:

- ► The perception of the roadway network's ability to meet evacuation traffic demand;

- The traffic control measures emplaced to improve flow or reduce congestion;
- The perceptions regarding how quickly the public responded to evacuation orders;
- The apparent volume of traffic during the evacuation;
- The duration of the evacuation event relative to clearance times; and
- Any traffic problems experienced during the evacuation.

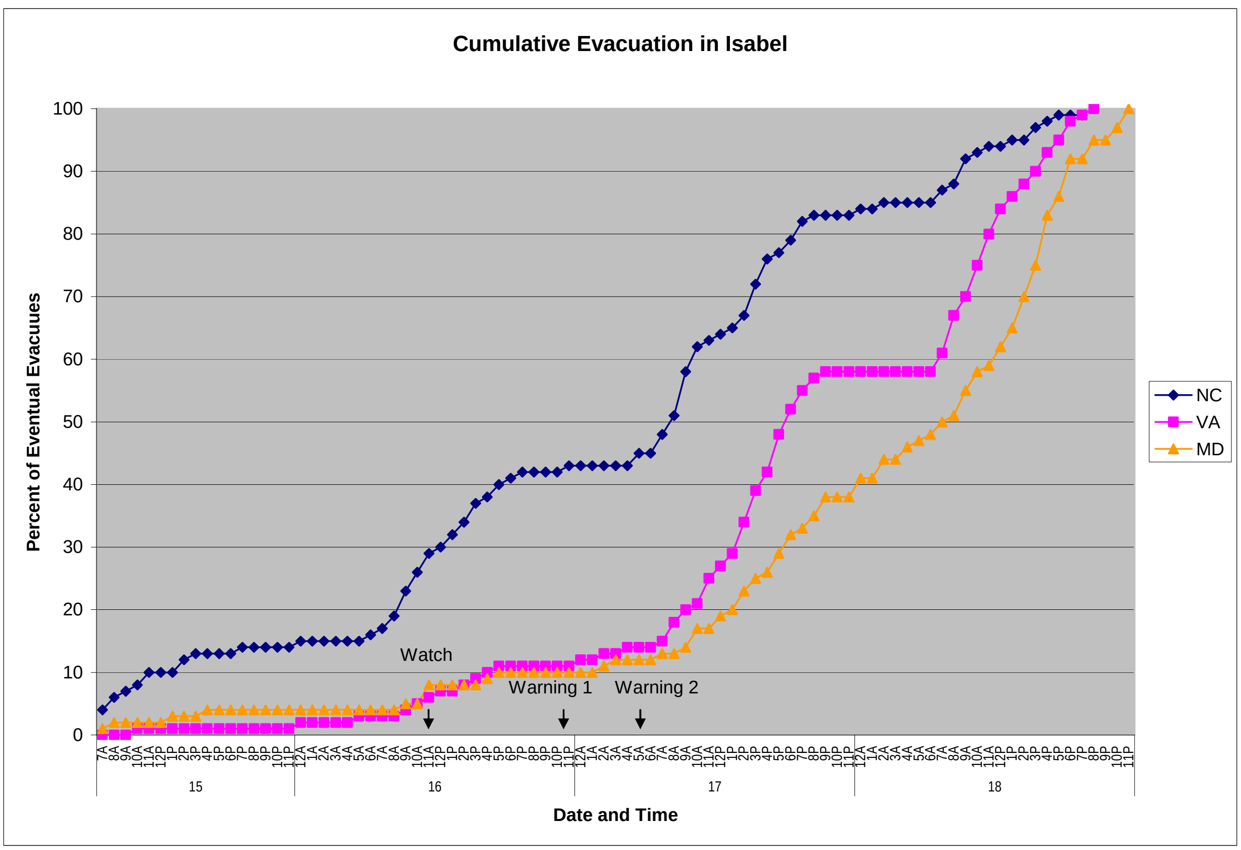
Based on observations from the local and state officials interviewed for this report, there were no major problems on the roadways that significantly hindered people's ability to leave the evacuated areas. Of the surveyed communities, only one incident of major traffic congestion was reported in Virginia on I-64 east of Richmond that extended from the I-64 / I-295 interchange back to approximately the first set of rest areas near Tallysville, a traffic queue of approximately 12 miles. No other interviews disclosed any additional anecdotal reports of major traffic congestion.

Furthermore, based on the survey responses for this effort and the data collected from the field for this storm, it appears that all evacuees specifically ordered to evacuate, or who decided to before arrival of hazardous conditions, were able arrive at a safe destination. There were no reports of evacuating vehicles stranded on the roadway in hazardous conditions due to impediments created by traffic congestion or other problems on local or regional roads.

Although the traffic and congestion situation on the regional roadway network did not reach critical status during Hurricane Isabel, there is no reason to believe that serious problems could not occur in future hurricane evacuation scenarios. Hurricane Isabel was a reasonably well behaved storm, moving on a course that was very consistent with the forecast tracks provided by the NHC, with very few meteorological surprises. The relative accuracy of the forecasts, which also extended out to five days, provided an ample amount of warning for officials in North Carolina and Virginia to prepare for and implement a successful evacuation. Additionally, in Virginia Governor Warner issued a State of Emergency on Sept. 15th and authorized local governments to issue mandatory evacuation orders as needed on September 17th. As reported in the State's Hurricane Isabel Assessment Report, his quick action caused many people in low-lying areas to leave early, before the storm arrived, avoiding any major evacuation problems. After the storm the Governor was praised for this decision during Hurricane Isabel.

Figure 7-1 below shows the hourly loading curves based on the behavioral data provided in greater detail in Chapter 6. The response or loading curves show that in all three states a substantial number of evacuees began moving well before the storm made landfall, or even before state and local officials conveyed any protective action decisions to the public. Approximately 25 percent of all households that evacuated for Hurricane Isabel in Virginia had done so even before the Governor's authorization and subsequent local orders on September 17th. Therefore, another factor that probably ameliorated traffic congestion during the Isabel evacuation is the reasonably gradual loading of the roadway network over a relatively long period of time.

Figure 7-1. Cumulative Evacuation in Isabel for North Carolina, Virginia and Maryland



Furthermore, based on behavioral data collected for this Post-Isabel Assessment, the participation rates in the zones ordered to evacuate were relatively low in all three surveyed states. Maryland's participation rates were further suppressed because relatively few local governments issued protective action directives for their populations, which resulted in correspondingly low evacuation-related traffic volumes. Certainly, the circumstances posed by Hurricane Isabel did not present an extreme evacuation scenario for the transportation networks in any of the three states. A minor change in any of the above variables during future hurricanes, even in a scenario exactly the same as this storm, could result in significantly different and less favorable evacuation transportation outcomes.

Table 7-1 below summarizes the information regarding transportation and evacuation related issues as provided by the surveyed state and local governments during this post-storm survey.

Table 7-1. Summary of Survey Responses for Evacuation

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response to Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process and Clearance Time [2]	Traffic Problems Experienced
NORTH CAROLINA						
Beaufort Co.	Adequate	Traffic Plan; Barricades; Traffic Control Points; Message Signs; AM Radio Messages	Normal	Heavy	3 – 4 Hours **Clearance Time:** 11.5 Hours for Cat 3	Downed Trees; Flooded Roads; Co. Roads Blocked with Debris; Power Outages
Bertie Co.	Adequate	NC SHP & SO Traffic Plan; Traffic Control Points; No Measures Reported	Normal	Normal	Not Specified **Clearance Time:** 8.5 Hours for Cat 1 - 2	No Reported Problems
Brunswick Co.	Fair	Traffic Plan; Barricades; Highway Reversal; Message Signs; Lock Down Drawbridges	Normal	Normal	Not Specified **Clearance Time:** 8.25 Hours for Cat 3	Construction; Standing Water in Roadway
Camden Co. & Pasquotank Co.	Fair	Traffic Plan; Traffic Control Points; Message Signs	Normal	Normal	Could Not Tell, No Big Influx Of Traffic **Clearance Time:** 8.5 Hours for Cat 3	None
Carteret Co.	Excellent	Traffic Plan; Traffic Control Points; Coord. Traffic Signals; Message Signs; Lock Down Drawbridges	Normal	Light	5 Hours **Clearance Time:** 9.5 Hours for Cat 3	None

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length Of Evacuation Process And Clearance Time [2]	Traffic Problems Experienced
NORTH CAROLINA (Continued)						
Chowan Co.	No Info Provided	No Traffic Plan; No Measures Employed	No Info Provided	No Info Provided	No Info Provided **Clearance Time:** 8.5 Hours for Cat 3	No Info Provided
Craven Co.	Good to Excellent	No Traffic Plan Reported; Barricades; Message Signs; Lock Down Drawbridges	Slow	Normal	No Info Provided **Clearance Time:** 11.5 Hours for Cat 3	Inadequate Route Signage; Flooded Roads; Minor Damage to Raods After Storm
Currituck Co.	Fair	NC SHP Traffic Plan; Control Points; Coord. Traffic Signals; Message Signs	Normal	Heavy	Phased over 2 Days **Clearance Time:** 17 Hours for Cat 3	No Significant Problems
Dare Co.	Fair	Traffic Plan; Traffic Control Points with Management Plan; Coord. Traffic Signals; Message Signs; Lock Down Drawbridges	Fast	Moderate	12 Hours **Clearance Time:** 17 Hours for Cat 3	Virginia DOT Did Not Lift Tolls in Timely Fashion
Hyde Co.	Fair	No Traffic Plan; Traffic Control Points	Slow	Normal	3 – 6 Hours **Clearance Time:** 11.5 Hours for Cat 3	None Reported
Jones Co.	Fair [3]	No Traffic Plan; None Reported	Normal	Heavy	2 Days **Clearance Time:** 11.5 Hours for Cat 3	No Significant Problems

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process and Clearance Time [2]	Traffic Problems Experienced
NORTH CAROLINA (Continued)						
Martin Co.	Adequate	No Traffic Plan; No Measures Used	No Evac Order Issued	Heavy	About 48 Hours No Evac Order Issued	None Reported
New Hanover Co.	Fair for Local Routes	No Traffic Plan; Traffic Control Points; Coord. Traffic Signals	No Evac Order Issued	No Evac Order Issued	No Evac Order Issued	No Info Provided
Onslow Co.	Good	Traffic Plan; Barricades; Roving Vehicle Assistance; Message Signs; Traffic Redirect	Normal	Normal	24 Hours **Clearance Time:** 7.25 Hours for Cat 3	Inadequate Signage; Flooded Roads; Accidents and Stalled Autos; Uncoord. Evac Timing
Pamlico Co.	Adequate	No Traffic Plan; No Measures Used	Slow	Normal	3 – 6 Hours **Clearance Time:** 11.5 Hours for Cat 3	Inadequate Traffic Control; Inadequate Signage; Not Enough Police Support
Pender Co.	Evacuation Order Not Issued	Traffic Plan; Not Applicable / Not Needed	No Official Evac Order Issued	No Official Evac Order Issued	No Official Evac Order Issued	Not Applicable / Not Needed
Perquimans Co.	No Info Provided	No Traffic Plan; NC SHP handled all traffic control	No Info Provided	Normal	No Info Provided **Clearance Time:** 8.5 Hours for Cat 3	No Info Provided

Survey Community	Perceived Capacity of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process And Clearance Time [2]	Traffic Problems Experienced
NORTH CAROLINA (Continued)						
Tyrell Co.	Fair	No Traffic Plan; DOT Control of Traffic Light on US 64; Traffic Control Points	Normal	Light	12 – 24 Hours **Clearance Time:** 11.75 Hours for Cat 1 - 2 on US 64	No Info Provided
Washington Co.	Excellent	Traffic Plan; AM Radio Messages	Normal	Heavy	Approximately 6 – 7 Hours **Clearance Time:** 11.75 Hours for Cat 1 - 2 on US 64	Accident and Stalled Autos
North Carolina Division of Emergency Management	Adequate	Not Applicable	Not Applicable	Not Applicable	Not Applicable	None Reported
VIRGINIA						
Accomack Co.	Good	No Traffic Plan; No Measures Used During Storm	Fast	Normal	5 – 10 Hours **Clearance Time:** 7.5 Hours for Cat 1	Lack of Signage for Shelters
Chesapeake	Fair	VDOT Evacuation Plan for the Region	Normal	Heavy	Within 24 Hours for the Region **Clearance Time:** 6 Hours for Cat 2	No Info Provided
Chincoteague	Adequate	No Traffic Plan; Roving Vehicle Assistance; Traffic Control Points; Lock Down Drawbridges	Normal	Normal	12 Hours **Clearance Time:** Included as part of Accomack Co. time	None Reported

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process and Clearance Time [2]	Traffic Problems Experienced
VIRGINIA (Continued)						
Gloucester Co.	Adequate	Traffic Plan; Traffic Control Points; Lock Down Drawbridge	Normal	Heavy	15 – 20 Hours **Clearance Time:** 10.5 Hours for Cat 4	Uncoordinated Traffic Signals; Backup from I-295 to I-64 Rest Areas for Unknown Reasons
Hampton	Adequate	VDOT Evacuation Plan for the Region; Coordinated Traffic Lights	Normal	Normal	No Info Provided **Clearance Time:** ~9 Hours for Cat 4 [4]	Backup from I-295 to I-64 Rest Areas for Unknown Reasons
Isle of Wight Co.	Fair	VDOT Evacuation Plan for the Region	Normal	Heavy	Within 24 Hours for the Region **Clearance Time** [5]	No Info Provided
Lancaster Co.	Adequate	No Traffic Plan; Barricades; Roving Vehicle Assistance; Message Signs	Slow	Light to Normal	2 – 4 Hours **Clearance Time:** 6.25 Hours for Cat 1	Downed Trees; Flooded Roads; Damaged Roads
Mathews Co.	Excellent	No Traffic Plan; No Measures Used	Fast	Heavier Than Usual	24 Hours **Clearance Time:** 6.25 Hours for Cat 1	Downed Trees; Flooded Roads; County Roads Blocked
Newport News	Fair	Traffic Plan; But They Were Not Put Into Place	Normal	Normal	No Info Provided **Clearance Time:** ~6 Hours for Cat 1 [6]	Backup from I-295 to I-64 Rest Areas for Unknown Reasons
Norfolk	[7]	VDOT Evacuation Plan for the Region	[7]	[7]	[7] **Clearance Time** [8]	[7]

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process and Clearance Time [2]	Traffic Problems Experienced
VIRGINIA (Continued)						
Northumberland Co.	Excellent	No Traffic Plan; AM Radio	Normal	Light	6 Hours **Clearance Time:** 6.25 Hours for Cat 1	None Reported
Poquoson	Unsatisfactory	VDOT Evacuation Plan for the Region; Roving Vehicle Assistance	Normal	Normal	2 Days **Clearance Time:** 6 Hours for Cat 1 [6]	Flooded Roads; Backup from I-295 to I-64 Rest Areas for Unknown Reasons
Portsmouth	Fair	VDOT Evacuation Plan for the Region	Normal	Heavy	Within 24 Hours for the Region **Clearance Time:** 6.25 Hours for Cat 1	No Info Provided
Richmond Co.	Excellent	No Traffic Plan; AM Radio	Normal	Light	6 Hours **Clearance Time:** 6.25 Hours for Cat 1	None Reported
Suffolk	Fair	VDOT Evacuation Plan for the Region; Coordinated Traffic Signals on US 58	Fast	Heavy	Within 24 Hours for the Region **Clearance Time:** 7 Hours for Cat 2	Unanticipated Volumes: Congestion and Traffic Jams; Uncoordinated Traffic Signals
Virginia Beach	Fair	VDOT Evacuation Plan for the Region	Normal	Heavy	Within 24 Hours for the Region **Clearance Time:** 11 Hours for Cat 2	No Info Provided
Westmoreland Co.	Excellent	No Traffic Plan; Barricades; AM Radio	Normal	Light	6 Hours **Clearance Time:** 6.25 Hours for Cat 1	None Reported

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process and Clearance Time [2]	Traffic Problems Experienced
VIRGINIA (Continued)						
York Co.	Fair	VDOT Evacuation Plan for the Region; SO Traffic Control Points	Normal	Normal	No Info Provided **Clearance Time:** ~6 Hours for Cat 1 [6]	Not Aware of Any Problems
Virginia Department of Emergency Management	Roadways Were Empty On Day Storm Made Landfall	Phased Evacuations; I-64 and I-295 Interchange Highway Reversal Plan (Not Used During This Event)	Not Applicable	Above Average Traffic	Not Applicable	Many Roads Closed At Height Of Storm; Norfolk to Portsmouth Mid-Town Tunnel Flooded
MARYLAND						
Anne Arundel Co.	No Info Provided	No Traffic Plan; Barricades; Roving Vehicle Assistance; Traffic Control Points; Message Signs; Radio Messages Live by PIO	No Evacuations Ordered	Light	Not Applicable	Traffic Diversions from Other Counties; Traffic Jams Caused by Closed Roads; Flooded Roads; Failed Traffic Signals Require Manual Operation
Baltimore Co.	Fair	Baltimore Police Traffic Management Plan; Barricades; AM Radio Messages	Fast	Normal	Roughly 24 Hours	Downed Trees; Flooded Roads; Damaged Roads

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length of Evacuation Process and Clearance Time [2]	Traffic Problems Experienced
MARYLAND (Continued)						
Baltimore City	No Evacuations Ordered	Traffic Plan; Roadway Monitoring System in downtown and on I-83, I-695 & I-295	No Evacuations Ordered	Normal	No Evacuations Ordered	No Info Provided
Calvert Co.	Excellent	Traffic Plan; Barricades; Traffic Control Points; AM Radio Messages	Normal	Normal	Less Than 6 Hours	Traffic Signals Didn't Work; Downed Trees; Flooded Roads; County Roads Blocked
Charles Co.	Adequate	No Traffic Plan; Barricades; Roving Vehicle Assistance; Traffic Control Points	Normal	Light	9 hours (from 7 pm to 4 am)	Inadequate Signage; Downed Trees; Flooded Roads; Damaged Roads; Accidents And Stalled Autos; County Roads Blocked
Harford Co.	No Evacuations Ordered	Traffic Plan; Barricades; Traffic Control Points	No Evacuations Ordered	No Evacuations Ordered	No Evacuations Ordered	No Info Provided
Howard Co.	No Evacuations Ordered	Police Dept. Traffic Management Plan; Barricades; Traffic Control Points	No Evacuations Ordered	Normal	No Evacuations Ordered	Downed Trees; Flooded Roads

Survey Community	Perceived Capacity Of Routes To Evacuation Demand [1]	Traffic Mgmt. Plan & Control Measures Employed	Perceived Public Response To Evacuation Notice	Traffic Volume During Evacuation Event	Length Of Evacuation Process And Clearance Time [2]	Traffic Problems Experienced
MARYLAND (Continued)						
Prince George's Co.	No Evacuations Ordered	Roads Closure Designated Evac Routes Plan; Barricades	No Evacuations Ordered	Light	No Evacuations Ordered	No Info Provided
Somerset Co. [9]						
St. Mary's Co.	Good	SO.& State Police Traffic Management Plan; Barricades; Roving Vehicle Assistance; Traffic Control Points	Normal	Normal	Approximately 6 Hours	Downed Trees; Accidents and Stalled Autos
Maryland Emergency Management Agency	Excellent	Traffic Management Plans for Chesapeake Bay Bridge; Nat'l Capital Region and Ocean City; Traffic Control Points; Message Signs	Not Applicable	Not Applicable	Not Applicable	Not Aware Of Any Major Problems

1 Survey responses were provided on a scale of 1 to 5, 1 = Unsatisfactory, 2 = Fair, 3 = Adequate, 4 = Good, 5 = Excellent
2 Virginia and North Carolina HES clearance times are for medium response curves and low tourist occupancy.
3 NC 58 is sufficient to handle traffic, but US 17 is insufficient for traffic demand.
4 Clearance time is for in-community destinations, does not factor in I-64 clearance time of 19.5 hours for the same scenario.
5 Community not included in original 1992 Virginia HES, no clearance time available.
6 Clearance time is for in-community destinations, does not factor in using I-64 of 10.5 hours for the same scenario.
7 Information obtained from presentation, specific information not provided.
8 Clearance time not specified since community's evacuation scenario assumption for protective action planning is not known or provided.
9 Evacuation from Smith Island is not done by vehicle.

Evacuation Traffic Information System (ETIS) Analysis

Given this storm and the states that it impacted, it will be difficult to fully assess the evacuation traffic demand forecast accuracy of ETIS. Of the three surveyed states, only North Carolina has the ability to input evacuation decisions and see the travel demand imposed on the roadway network as a result of those local government orders. Virginia and Maryland can input their local government evacuation decisions; however there is no transportation-related data associated with those choices and consequently no forecast is developed for evacuation traffic congestion. For those states ETIS is an information tool only. Another issue with assessing ETIS against the Hurricane Isabel scenario is that not all at-risk counties included in the most recent HES for North Carolina (Year 2002) are included in ETIS. Only the following counties have the ability to input their evacuation decisions into ETIS: Beaufort, Brunswick, Carteret, Currituck, Dare, Hyde, New Hanover, Onslow, Pamlico and Pender. Of these counties all but New Hanover and Surf City in Pender County ordered their residents to undertake protective actions during Hurricane Isabel. The counties included in the 2002 HES that did evacuate for Hurricane Isabel, but are not included in ETIS are: Bertie, Camden, Chowan, Craven, Jones, Martin, Pasquotank, Perquimans, Tyrell and Washington Counties. Therefore, ETIS currently only has a limited capability to develop a complete picture of an evacuation scenario for North Carolina during a particular storm event.

Nonetheless the evacuation decisions of the applicable counties in North Carolina were input into ETIS, and the results seem reasonably consistent with the reports of traffic congestion on the evacuation roadway network from the surveyed counties. The results of ETIS, given an approximation of the decisions and other evacuation variables from the counties during Hurricane Isabel, are shown in Table 7-2 and Figure 7-3 below.

In Table 7-2 the total number of vehicles forecast to use certain major roadway segments during Hurricane Isabel is provided, as well as the expected hours of congestion (the approximate number of hours each roadway segment must operate at maximum hourly capacity in order to process all the vehicles forecast to use it during an evacuation). These congestion figures do not mean that the roadway will be congested for the number of hours specified in the table, but instead provide a relative measure of each roadway segment's traffic demand against its ability to process it. Depending on other transportation variables such as roadway loading, these congestion figures only provide a ranked indication of which roadways will be the most impacted and therefore, which will need the most amount of operational attention during an evacuation. Figure 7-3 provides a map depicting the relative congestion of each roadway for the scenario that roughly approximates Hurricane Isabel. In both the table and the drawing the roadway volumes and congestion levels in ETIS are probably lower than in reality since not all evacuating counties could be input into the program for the travel demand forecast. Nonetheless the ETIS results are reasonably consistent with the roadway and other evacuation observations made by the surveyed counties in this post-storm assessment.

Figure 7-2. Meeting with Local Emergency Management Officials in Chesapeake, VA

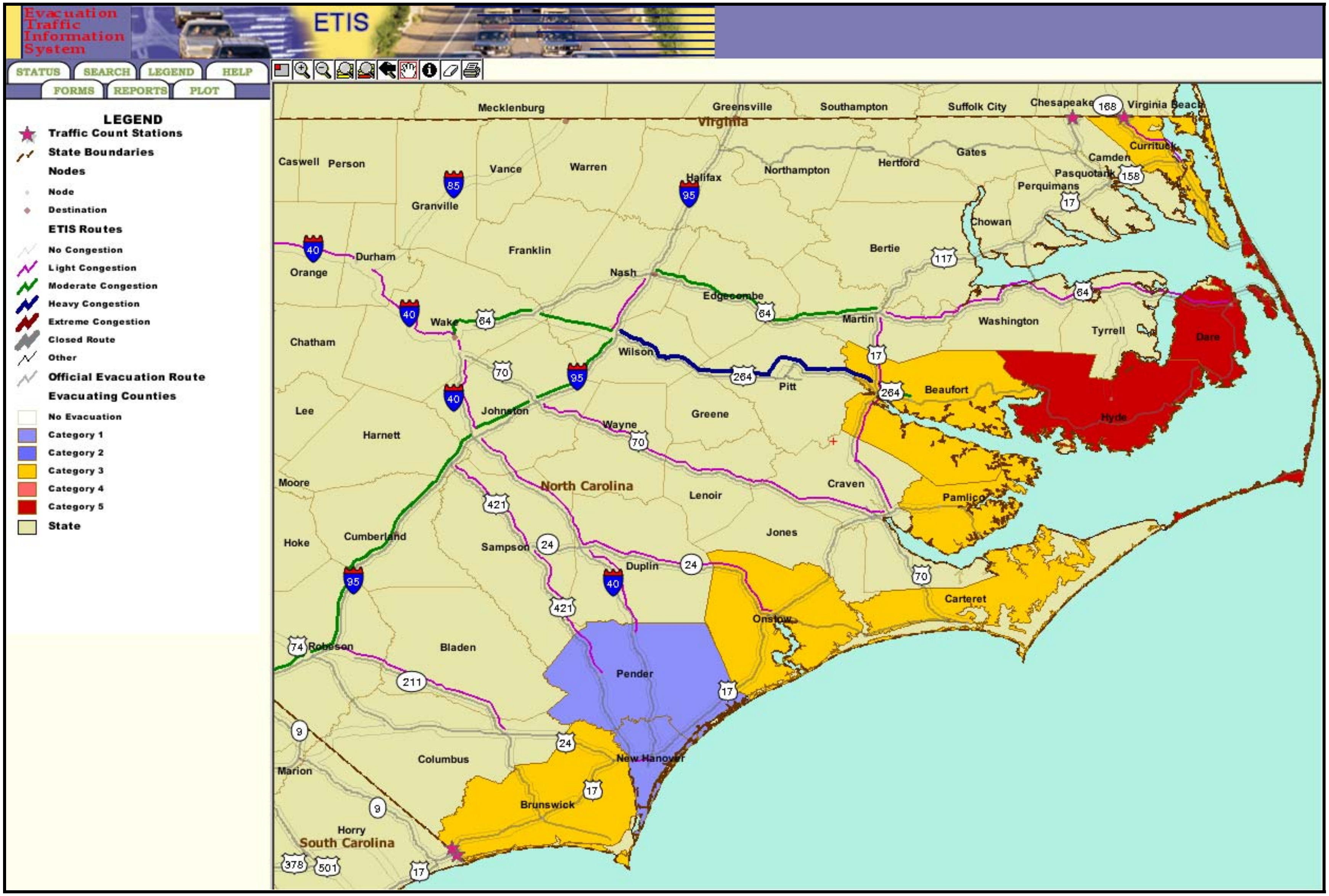
Table 7-2. Forecast and Traffic Counter Comparison for North Carolina

ETIS FORECAST FOR NORTH CAROLINA					
Hurricane Isabel					
			ETIS [1]		
Segment Start	Segment End	Number of Evacuating Vehicles at Traffic Counter [2]	Modeled Hourly Capacity	Forecast Traffic Volume (Vehicles)	Forecast Hours of Congestion
I-95 Northbound					
US 64	Virginia Line	5,987	3,000	210	1
I-95 Southbound					
Virginia Line	US 64	6,679	3,000	5,460 [3]	2
US 64	US 264		3,000	5,850	2
US 264	US 70		3,000	15,163	5
US 70	I-40		3,000	21,533	7
I-40	US 421		3,000	17,759	6
US 421	SR 87	6,916	3,000	18,848	6
SR 87	US74		3,000	13,732	5
US 64 Westbound					
US 264	SR 94	974 [4]	2,000	5,460	3
SR 94	US 17		2,000	6,360	3
US 17	I-95		2,000	8,945	4+
I-95	US 264		2,000	3,095 [5]	2+ [5]
US 264	I-40		2,000	9,046	4+
US 264 Westbound					
US 17	I-95		2,000	18,360	9
I-95	US 64	7,154	2,000	9,046	5
US 17 Westbound [6]					
US 70	US 264		1,000	1,980	2
US 264	US 64		2,000	2,165	1
US 70 Westbound					
US 17	I-95	6,290	2,000	6,370	3+

ETIS FORECAST FOR NORTH CAROLINA					
Hurricane Isabel					
			ETIS[1]		
Segment Start	**Segment End**	**Number of Evacuating Vehicles at Traffic Counter [2]**	**Modeled Hourly Capacity**	**Forecast Traffic Volume (Vehicles)**	**Forecast Hours of Congestion**
SR 24 Westbound					
US 17	I-40	713	880	931	1
I-40 Westbound					
SR 117	SR 24		6,000	6,764	1+
SR 24	I-95		6,000	7,675	1+
I-95	US 64	11,975	3,000	10,943	4
US 64	I-85 E		4,500	11,248	2+
US 421 Westbound					
US 17	SR 53		1,000	700	<1
SR 53	I-95		1,000	1,994	2
SR 211 Westbound					
US 17	US 74/76		880	464	<1
US 74/76	I-95		880	1,988	2
SR 168 Northbound					
US 158	Virginia		880	1,260	1+

1 Based on the following scenario: Beaufort-Cat 3, 50% participation; Brunswick-Cat 3, 10%; Carteret-Cat 3, 50%; Currituck-Cat 3, 30%; Dare-Countywide, 40%; Hyde-Countywide, 50%; Onslow-Cat 3, 10%; Pamlico-Cat 3, 50%; Pender and New Hanover-Cat 1, 60% (spontaneous evacuations – no orders issued). No other counties currently can input evac decisions into ETIS.
2 Total number counted over two day period, generally from 9/16/03 to 9/17/03.
3 Does not include traffic from Virginia evacuations.
4 One day only reading (9/17/03).
5 Estimate based on number of vehicles not continuing on I-95 and US 64 / I-95 interchange.
6 Traffic counter on US 17 not on a segment modeled by ETIS.

Figure 7-3. ETIS Travel Demand Forecast Map for North Carolina During Hurricane Isabel



North Carolina Traffic Counter Data

<u>US 64</u>

Figure 7-4. Observed vs. Historical Hourly Vehicle Counts on US 64

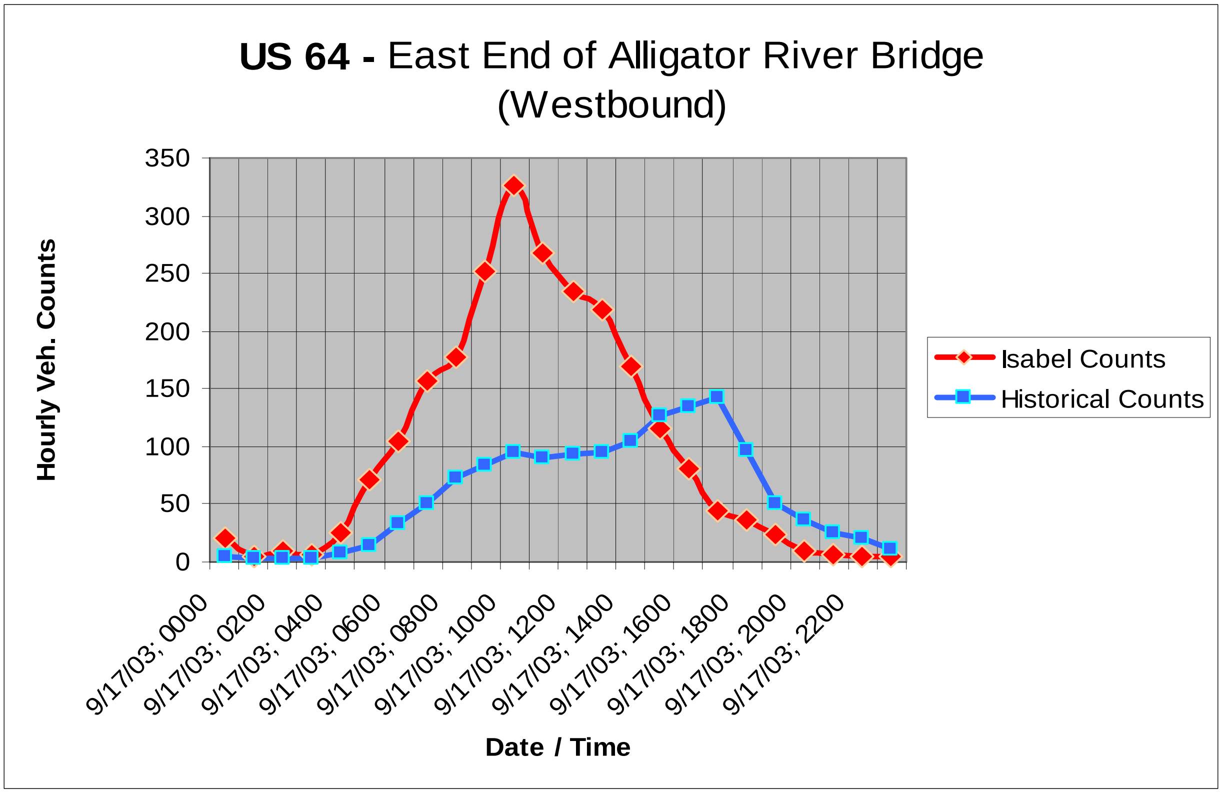
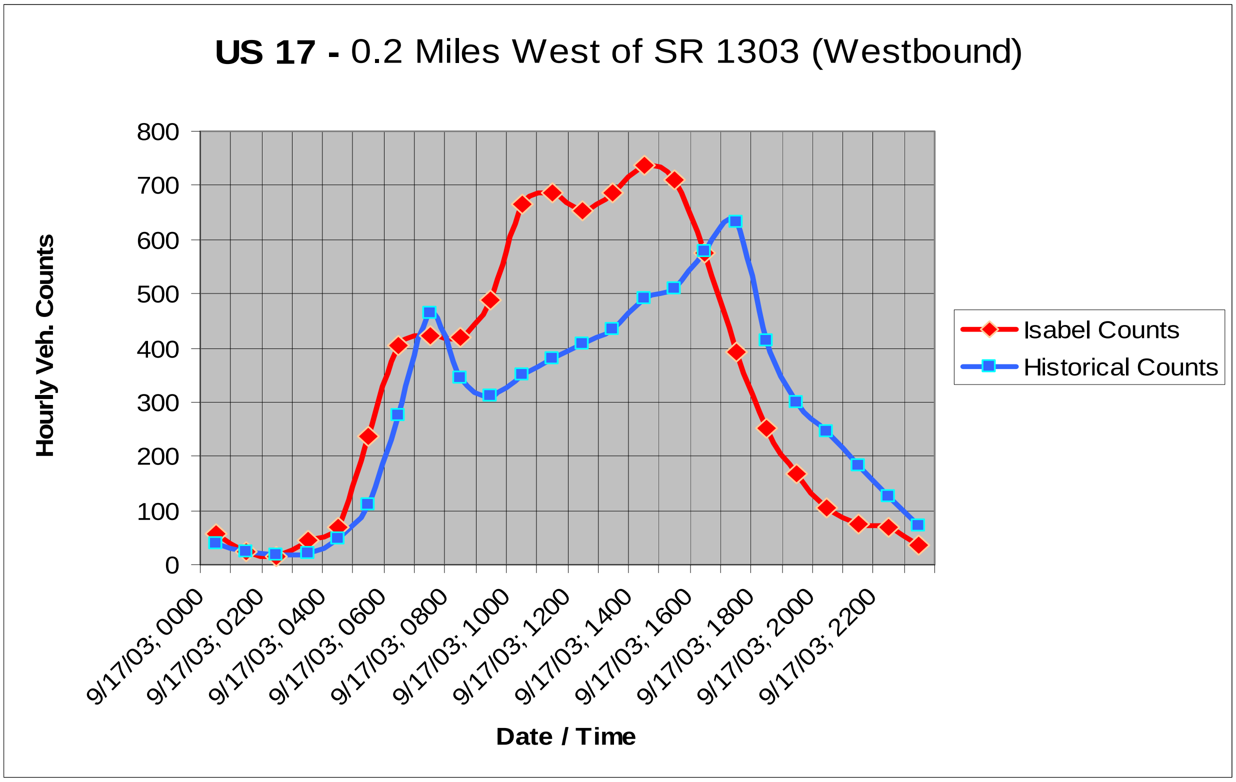


Figure 7-4 above shows the results from an hourly traffic counter on westbound US 64 on the eastern abutment of the Alligator River bridge primarily used by Dare County for evacuation. The counter was not operational on September the 16th and the county issued a county-wide evacuation order at noon on the 17th. Apparently many residents decided to evacuate before the evacuation order was issued by local officials. The likely duration of the evacuation based on the sensor results for September 17 th is approximately 11 to 12 hours. A total of 2,373 vehicles traveled in this direction just prior to the hurricane, indicating that 974 additional vehicles used the roadway above the normal historical daily volume of 1,399. The figure at this counter is well below the total travel demand value forecast by ETIS, but this traffic counter does not include the number of vehicles on September the 16th.

US 17

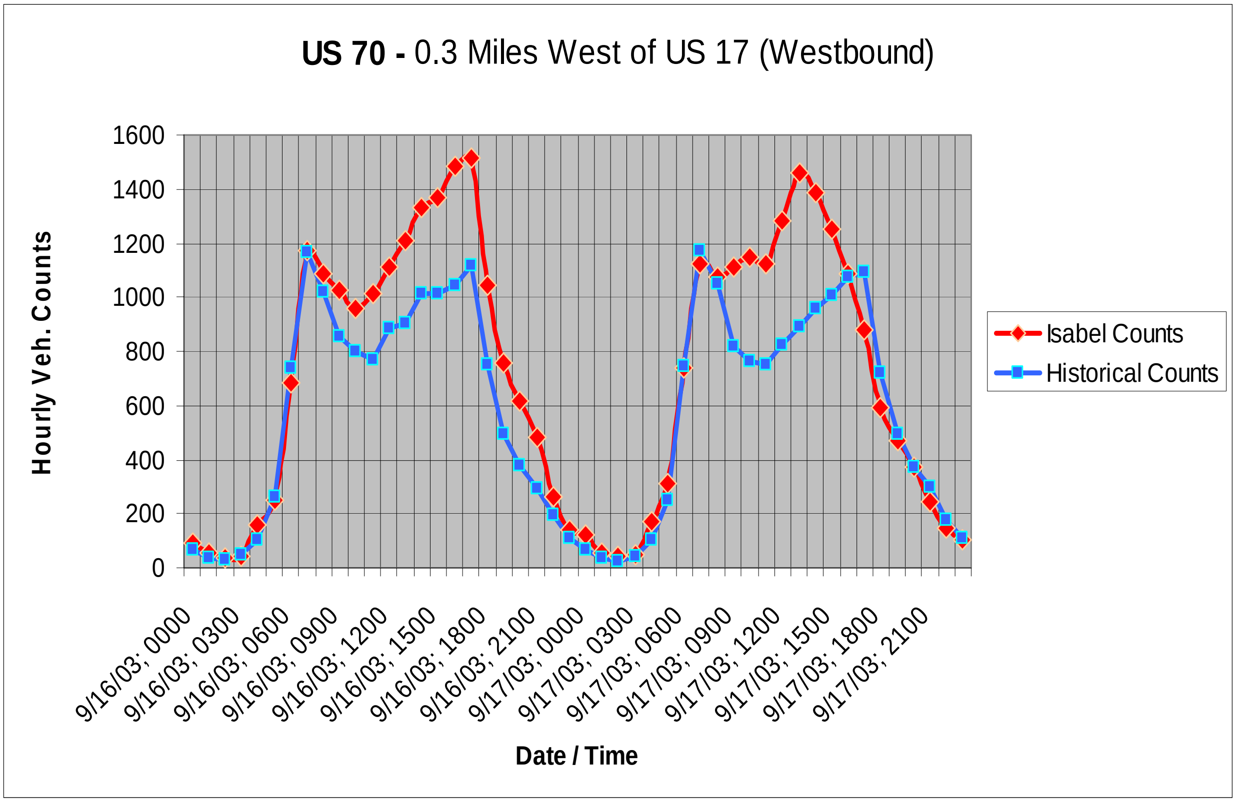
Figure 7-5. Observed vs. Historical Hourly Vehicle Counts on US 17



A counter on US 17, just west of SR 1303 in Pasquotank County (See Figure 7-5) shows the hourly traffic for September 17th. Unfortunately this sensor was not operational on September the 16th. Evacuations were ordered for Currituck County, effective for the Outer Banks at noon on September the 16th and for the mainland and the rest of the county on the 17th at 10:00 AM. Camden and Pasquotank Counties, which also must rely on the roadway for evacuation, issued voluntary orders at 3:00 PM on September 16th and mandatory orders at 2:00 PM on the 17th. The increase in traffic volumes probably caused by evacuating vehicles started at 6:00 AM, on the 17th and continued for approximately 12 hours. Despite the number of vehicles being abnormally above the historical hourly volumes for that roadway on September 17th, the road never reached saturation level, consequently the traffic congestion on this roadway was probably minimal. For the 24 hour period shown, this segment of US 17 processed 7,995 vehicles, or 1,219 vehicles above the typical daily total volume of 6,776.

US 70

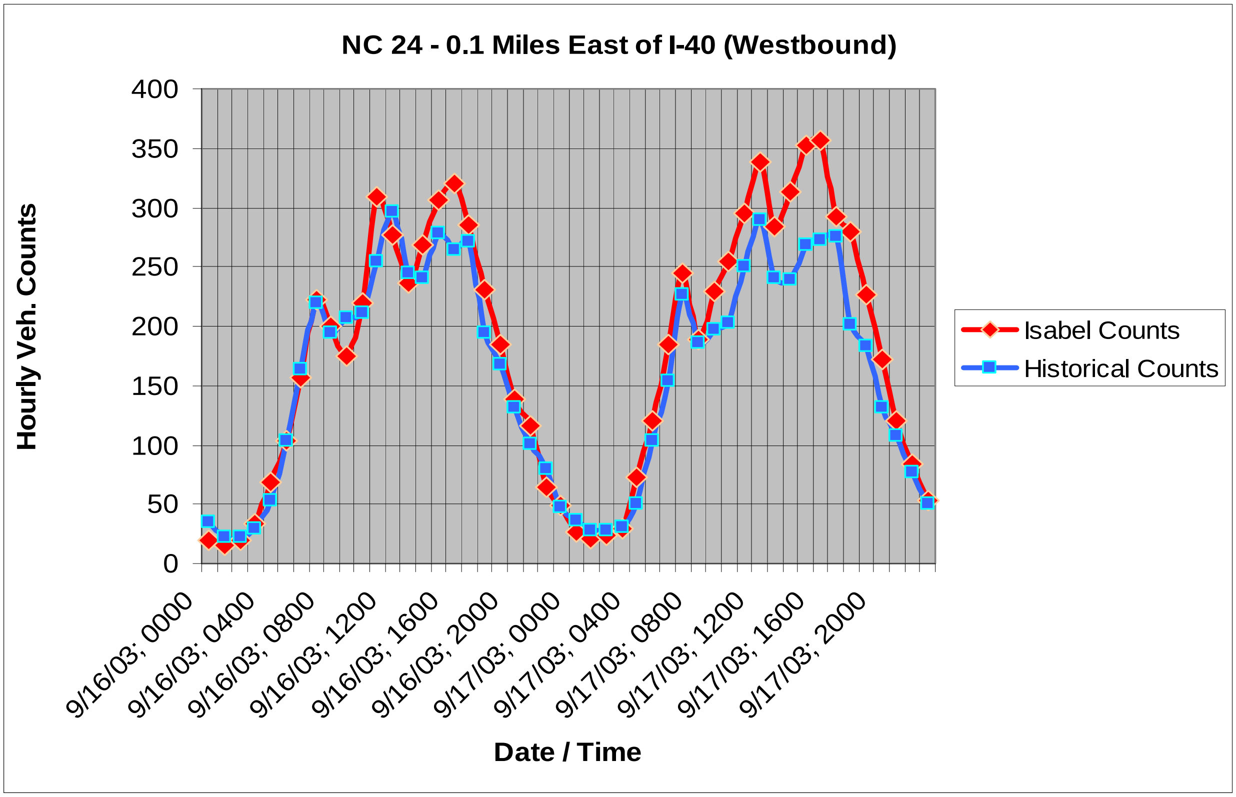
Figure 7-6. Observed vs. Historical Hourly Vehicle Counts on US 70



A traffic sensor on US 70 just west of US 17 (Figure 7-6 above) recorded a total volume of 34,249 vehicles for September 16th and 17th, 6,290 vehicles over the normal historical total volume of 27,959 for both days. This roadway segment is the likely evacuation route for Carteret, Craven and Pamlico Counties. Carteret County issued voluntary evacuation orders at 7:00 AM on September 16th and mandatory orders at 7:00 AM on the 17th. Craven County issued a voluntary evacuation order for its residents on September the 16th, followed by Pamlico County at 3:00 PM on the 17th. Despite traffic being above the normal hourly average for 20 hours for both days, the volume at this segment on US 70 never approached its hourly maximum. The total travel demand forecast by ETIS was 6,370 vehicles which is very close to the atypical number of vehicles recorded by this traffic sensor during Hurricane Isabel.

NC 24

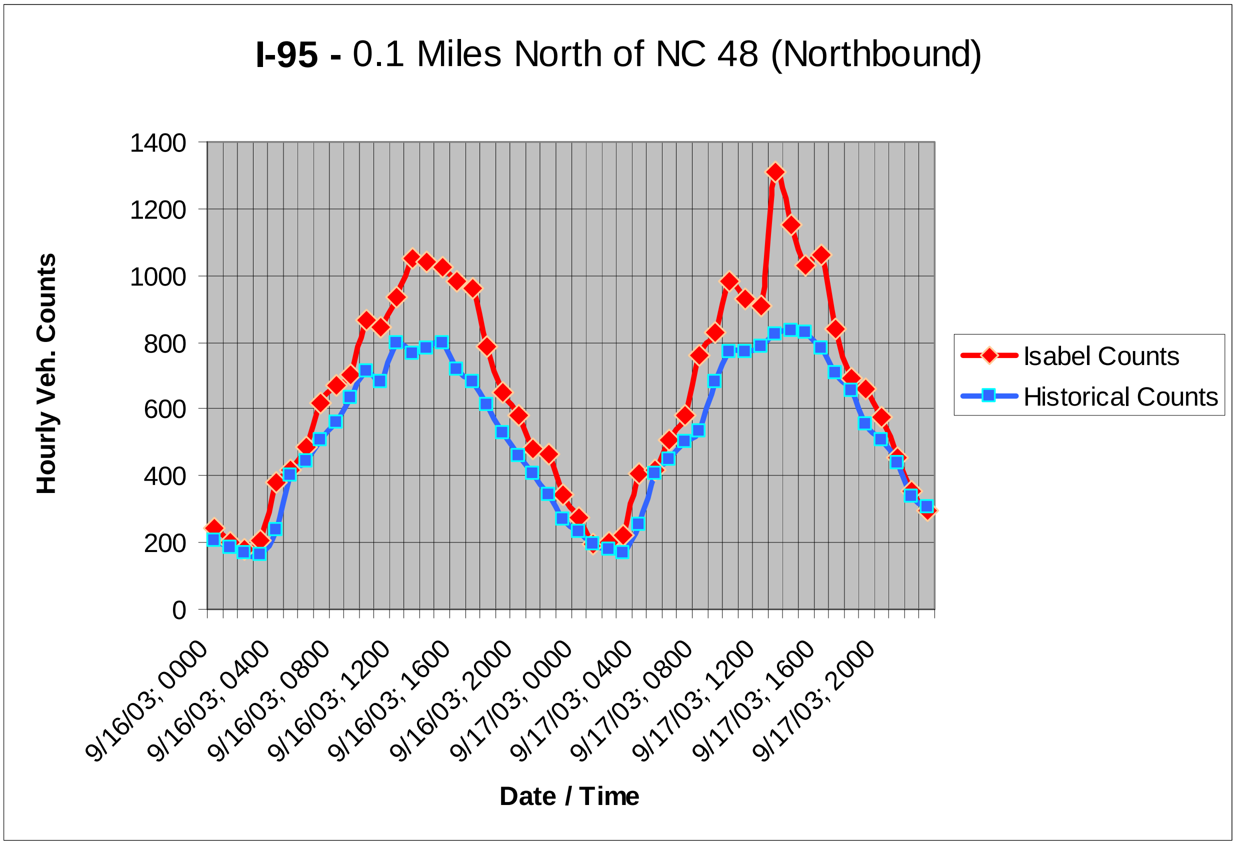
Figure 7-7. Observed vs. Historical Hourly Vehicle Counts on NC 24



A counter located near the intersection of NC 24 with I-40 recorded slight increases in traffic, probably due to evacuations on both the 16th and 17th of September. This traffic counter captures the evacuation trips that are likely to leave Onslow County and a smaller proportion of the evacuation trips from Carteret County. On the 16th of September the vehicles counted on NC 24 were negligibly higher than normal traffic volumes. However on the 17th, from 8:00 AM to 9:00 PM a total of 713 additional vehicles used the road segment. This slight increase in traffic for that day is consistent with the mandatory evacuation orders issued in Carteret County and the voluntary order from North Topsail Beach in Onslow. Figure 7-7 above displays the hourly observed against the historical hourly values for that counter for both the 16th and 17th of September. Figures for the 18th were not included since the observed counts were significantly below the typical historical counts for that location. The ETIS forecast for the total evacuation travel demand on this roadway segment was 931 vehicles, only slightly higher than the actual number of additional vehicles that were recorded by this sensor.

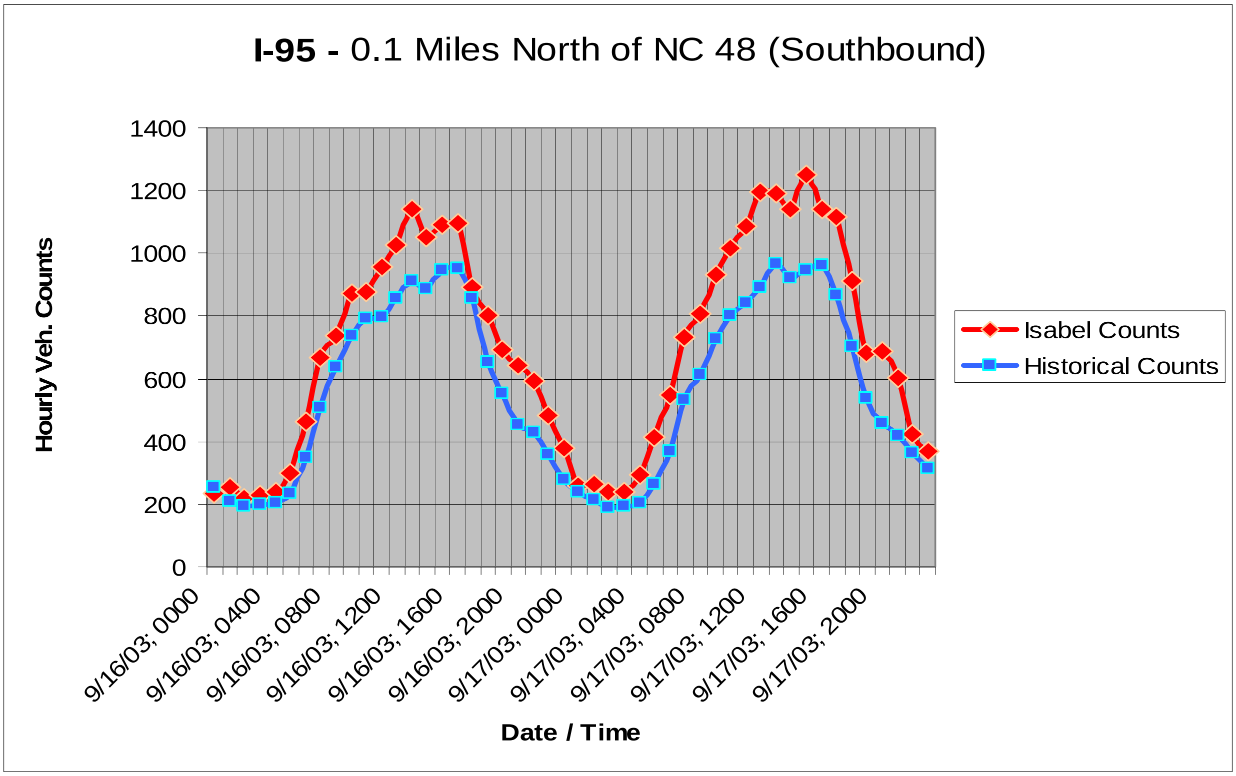
I-95 Near NC 48

Figure 7-8. Observed vs. Historical Hourly Vehicle Counts on I-95 Northbound



The counter on I-95 near NC 48 (See Figure 7-8) recorded higher than normal traffic volumes in both directions on September the 16th and 17th, 2003. The northbound direction documented an additional 5,987 vehicles spread over both days. This traffic began on both days at about 7:00 AM and consistently maintained higher than normal hourly counts until approximately 9:00 PM. The hourly counts in the northbound direction reached an all time high for both days of around 1,400 vehicles per hour, well below the hourly maximum service volume for that segment. Nearly the same number of additional vehicles used the northbound lane of I-95 on both days indicating an even loading of evacuation traffic over a relatively long period of time. The gradual loading of this segment over two days ensured that it did not become overwhelmed with vehicles at any time during the evacuation.

Figure 7-9. Observed vs. Historical Hourly Vehicle Counts on I-95 Southbound



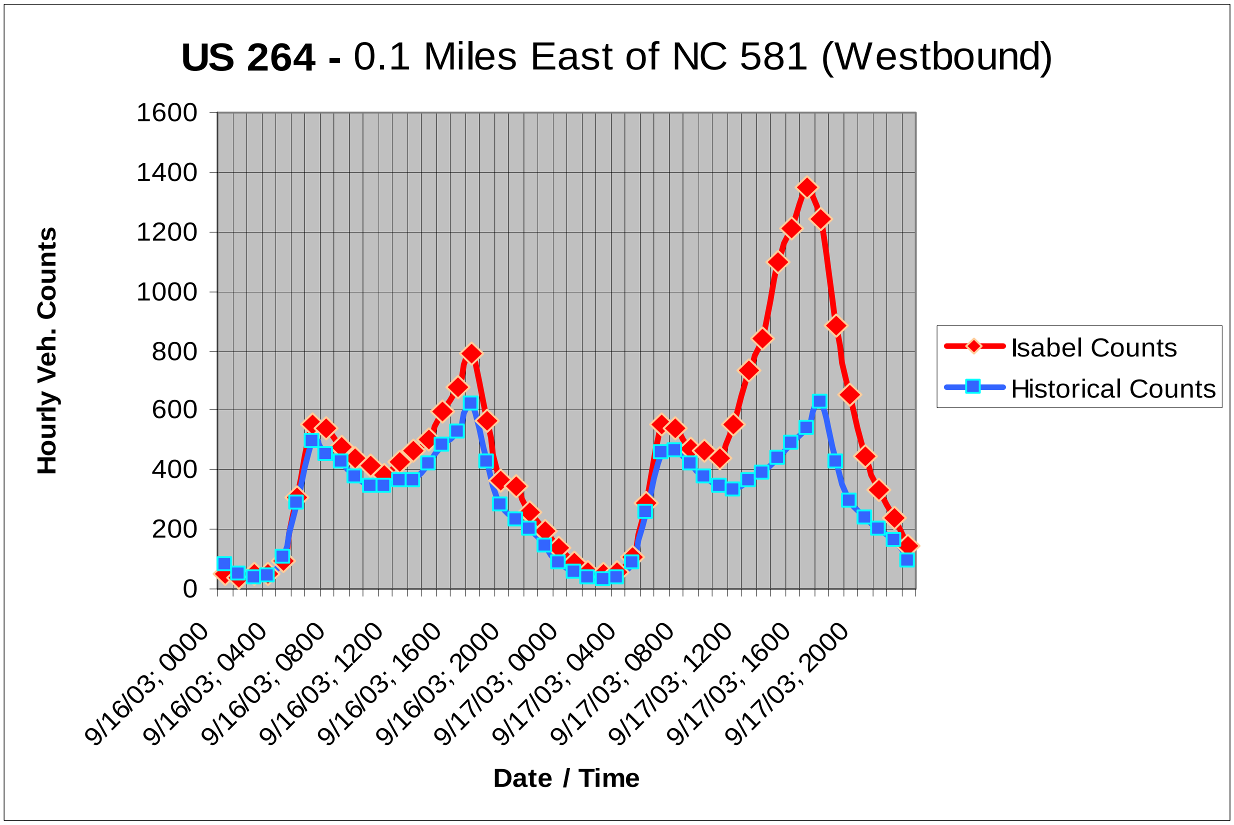
The same counter in the southbound lanes of I-95 (Figure 7-9) also registered an increase over the historical average in the overall number of vehicles for both days. On the 16th, 2,680 additional vehicles used the southbound side of I-95 near Rocky Mount, whereas on September the 17th a total of 3,999 vehicles over the typical historical average used that segment of interstate highway. The hourly traffic did not significantly increase over the historical averages on the 16th until midmorning and remained consistently high until midnight. Based on this traffic counter, evacuating traffic appears to have begun early, at about 3:00 AM on September 17th and did not abate until approximately 10:00 PM that evening. At no point on either day did the number of vehicles approach the hourly maximum service volume for this segment.

ETIS forecasted many fewer vehicles traveling north on I-95 at this counter, 210 versus the nearly 6,000 additional vehicles that used this segment of I-95 in a northbound direction. There are many variables that could account for this significant difference, although a plausible explanation could be that many of the vehicles that may use I-95 northbound cannot be committed to evacuate in the current version of ETIS. Currently ETIS lacks the capability to add the vehicles for evacuations from many of the northern tier of coastal counties. Therefore the evacuation travel demand for Tyrrell, Washington, Martin, Bertie, Chowan Perquimans, Pasquotank and Camden Counties cannot currently be committed to North Carolina's evacuation roadways in ETIS. Many of the vehicles leaving these non-committable counties would most likely travel northbound on I-95, possibly headed to locations in Virginia. According to behavioral data in the previous chapter, 22 percent of the total evacuees interviewed in North Carolina went to Virginia during Hurricane Isabel.

The disparity between the actual and ETIS forecasted numbers was much smaller in the southbound direction of I-95. The counter documented 6,679 additional vehicles over the two day period, whereas ETIS estimated that 5,460 vehicles would use this roadway segment.

<u>US 264</u>

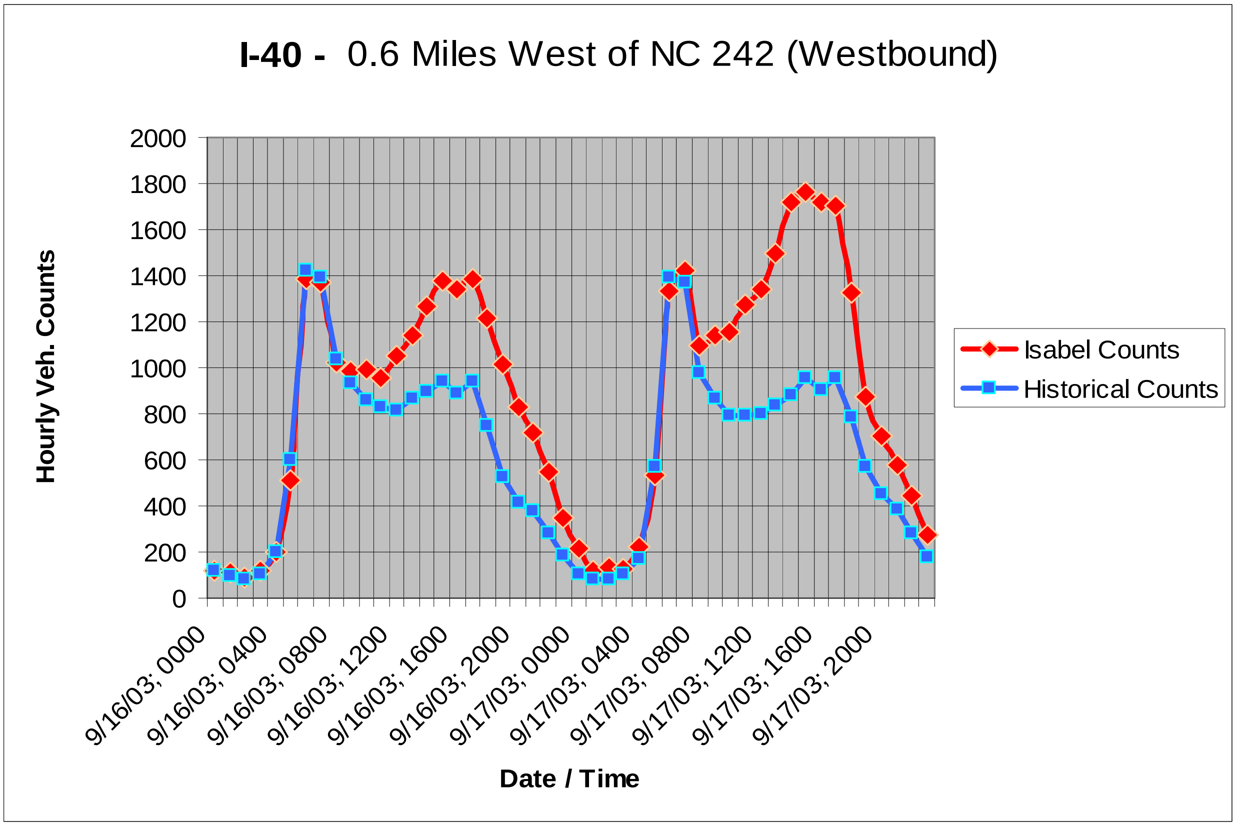
Figure 7-10. Observed vs. Historical Hourly Vehicle Counts on US 264



A traffic counter located on US 264 just west of I-95 in the vicinity of Wilson documented over September 16th and 17th a total of 7,154 additional vehicles, probably as a result of evacuation orders primarily in Hyde and Beaufort Counties. The evacuation traffic on the 16th constituted only 20 % of that total figure indicating that evacuations for these two counties didn't start in earnest until September the 17th. Hyde County issued voluntary evacuation orders at noon on the 16th and upgraded them to mandatory at 8:00 AM on the 17th, whereas Beaufort County issued their voluntary evacuation order later that same day at 4:00 PM. The hourly traffic volumes did not deviate significantly from the historical averages until 10:00 AM on the 17th and remained consistently higher than the average until about 11:00 that evening. Figure 7-10 above shows the data collected by the US 264 counter near Wilson. ETIS forecast that this roadway segment would experience an additional travel demand of 9,046 vehicles, slightly higher than the 7,154 additional vehicles that actually activated this sensor.

I-40

Figure 7-11. Observed vs. Historical Hourly Vehicle Counts on I-40

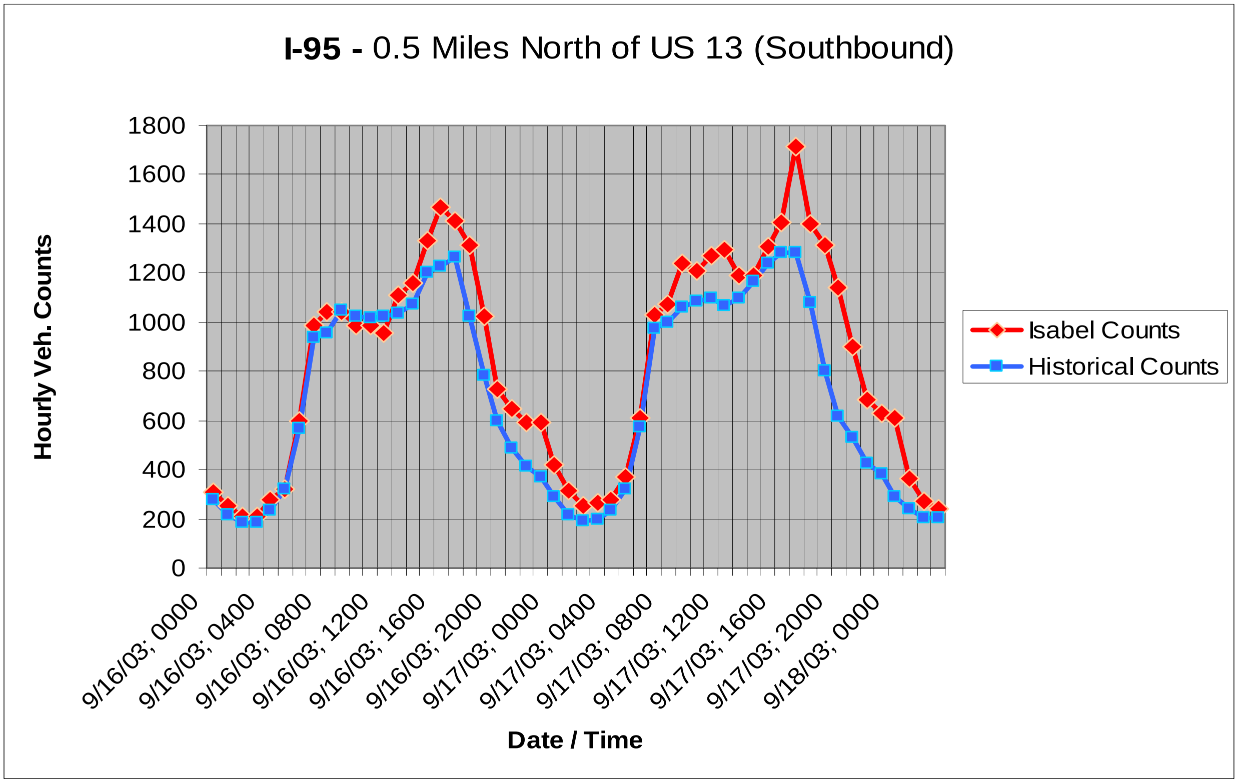


On September 16th and 17th, 2003, on I-40 westbound, a counter near NC 242 recorded a total volume of 42,809 vehicles, 11,975 more than the normal historical volume for those two days (See Figure 7-11 above). This counter is located just to the northwest of the I-40 interchange with I-95, so it is difficult to differentiate what proportion of traffic from either interstate route used this segment in traveling to Raleigh and beyond. Nonetheless, according to this counter evacuation traffic began at approximately 9:00 AM on September the 16th and continued all that day until approximately midnight. On the next day, the evacuation traffic began at about the same time in the morning as the previous day and did not abate until midnight, approximately five hours before the arrival of tropical storm force winds in that vicinity. Interestingly, none of the most likely counties to use I-40 as the primary evacuation route issued evacuation orders on September the 16th and only Onslow and Brunswick Counties did so on the 17th. Despite a substantial number of additional vehicles using this particular segment of I-40 during both days the hourly counts never came close to surpassing the maximum hourly service volume for this segment of 3,000 vehicles per hour.

According to this traffic counter almost 12,000 additional vehicles used this portion of I-40 on the 16th and 17th of September before Hurricane Isabel. The ETIS program estimated that approximately 10,943 evacuating vehicles would use this roadway, based on a reasonably high participation rate from the areas immediately along the coast in New Hanover and Pender Counties. Given the size of the storm and its relative longevity on the radar screen, it is reasonable to believe that many of the most-vulnerable residents and visitors would elect to evacuate, regardless of what local orders are in effect.

I-95 North of US 13

Figure 7-12. Observed vs. Historical Hourly Vehicle Counts on I-95 Southbound



A counter on I-95 southbound near Fayetteville recorded for the two day period of September 16th and 17th a total of 43,523 vehicles on that segment, 6,916 vehicles more than the historical average of 36,607. These nearly 7,000 additional vehicles moving southbound on I-95 were probably predominantly evacuees. The counter reflects that the evacuation traffic began in earnest at about 1:00 PM on September the 16th and continued well into the evening hours, finally abating about midnight. On the 17th, the counts again increased significantly over the hourly average at 9:00 AM in the morning and remained above normal until 2:00 AM on September the 18th, approximately five hours before tropical storm force winds arrived at that location. The peak count for both days was at 5:00 PM on September 17th when more than 1,700 vehicles used that roadway segment; still, that hourly figure was well below the service volume of 3,000 vehicles per hour. The data for that counter is above in Figure 7-12. The ETIS forecast of 18,848 vehicles was considerably higher than the actual number recorded at this particular counter.

Not all of the observations and recommendations below regarding evacuation are a direct consequence of lessons learned, specific requests, or situations encountered during Hurricane Isabel. Fortunately, this particular evacuation event did not create any major operational issues that can serve as a strong rationale for proposing significant corrective actions. Therefore, some of the remarks and suggested remedies below have been deduced from the experiences and circumstances provided by the hurricane and address programmatic, or more comprehensive policy issues in the National Hurricane Mitigation and Preparedness Program (NHMPP).

1. There were no indications from state and local emergency management officials in any of the three surveyed states that they used or even had direct access to Intelligent Transportation Systems (ITS) data during Hurricane Isabel. Clearly all three states have ITS measures in place, but no jurisdictions suggested that the data was shared with them, or provided directly to their EOCs in support of their evacuation operations. The assessments of the evacuation situation during Isabel provided by state and local emergency management agencies apparently were based on interpretations from the field and therefore mostly subjective. Even reports of the few traffic problems that did occur were anecdotal and could not be corroborated by hard evidence. That is not to say that the reports of traffic conditions were inaccurate, just that this type of information is more difficult to use operationally to address evacuation issues during an event.

   The deployment of more ITS along the nation's roadway network provides emergency management and other government officials with a tool to better manage evacuations during hurricanes and other events. The various types of ITS provide state and local emergency management the means to collect quantitative data regarding the progress of an evacuation. ITS capabilities also provide a method for communicating with evacuees, either before they begin their travel, or once they are already underway.

   By far the most prevalent ITS equipment in any state is the traffic counter; normally a loop in each lane of a roadway that senses and records the number of vehicles crossing it during any given period. As demonstrated with the data from the North Carolina system of traffic counters, the benefits of having this data in state and local emergency operations centers could revolutionize traffic management, sheltering and emergency communications operations for evacuations from any hazard. In these three states, as well as many others, there are two major impediments to making these common ITS measures as they are currently deployed in many areas truly useful for emergency response operations:

a. Many traffic counters, especially those on rural roadways away from urban centers, do not collect and transmit their information in near real time; and
b. The number of traffic counters is normally limited and their distribution usually concentrated on urban roadways, with very sparse coverage in rural areas.

The traffic counter data presented in this report for North Carolina during Hurricane Isabel is not collected and stored in near real time and there is no capability to provide access to those figures as they are observed. This arrangement is by no means unique to North Carolina. Up to now the traffic counters in the rural areas of most states have been used as a tool for transportation planning purposes. For most traffic counters the hourly traffic volume figures are downloaded at daily to weekly intervals and archived at a central location. The DOT staff must then compile and manipulate the data well after it is recorded, transmitted and stored in order to make it useful and available to outside users. In urban areas counter and roadway monitoring data is collected and conveyed in near real time to local traffic management centers (TMC) where it is used to manage normal traffic volume issues during rush hours and other peak travel periods. Even with near real-time traffic counter capabilities, that information is not readily available at state or local emergency operations centers where the data can have far wider applications than simply monitoring the routine flow of traffic.

In the areas specifically impacted by Hurricane Isabel, Maryland has the Coordinated Highways Action Response Team, or CHART, and Virginia has the Smart Traffic Centers in Hampton Roads, Richmond and Northern Virginia. These systems provide access to traffic volume information in near real time, but they are relegated mostly to the urban areas and roadways. Hurricane evacuations impose large traffic volumes on an extensive network of roads well beyond the urban fringe, on segments and at intersections that have no daily significance for traffic operations. Unfortunately, many of the critical links and nodes for local and regional evacuation are on road segments in rural areas. Traffic counters in rural areas are not normally located with the intent of collecting real time hourly volumes and average speeds during hurricane evacuations. Therefore many of these critical links on the evacuation transportation network do not have the benefit of a traffic counter nearby.

The deployment of real-time traffic counters specifically located at critical points on the evacuation roadway network coupled with the means to remotely access the data as it is collected would provide state and local emergency management with a wealth of useful information for response operations. With this data, state and local emergency management could foresee traffic problems and implement solutions more proactively; exert more influence over the operation of host shelters; as well as develop more effective emergency information to alert evacuees of potential trouble spots. Traffic counters in concert with other ITS measures such as 511, dynamic message signs, highway advisory radios (HAR) and traffic cameras on the roadway may be the most effective and cost efficient means of addressing many of the serious hurricane evacuation problems in this country.

The NHMPP must develop an agenda that champions the integration of emergency management needs into the planning process for the deployment of ITS measures. Federal, state and local transportation officials must recognize that in addition to ITS' evident role as a daily traffic operations tool for dealing with urban traffic congestion, it also has a less obvious but equally important function in maximizing public safety during evacuations.

Recommendation: Increase the national emphasis to integrate emergency management requirements into the ITS architecture at the federal and state level.

2. Currently, although the evacuation routes for Maryland and Virginia are displayed on the ETIS map, they do not have the capability to see the impacts of their evacuation decisions on the evacuation roadway network. During the Post-Isabel interviews, both Virginia and Maryland's Emergency Management Agency (MEMA) expressed their interest in getting travel demand forecasts from ETIS. Although the NHMPP has identified making both states fully functional as a high priority project for ETIS improvements, no funds have yet been earmarked for that effort.

   Recommendation: Expedite the development of travel demand modeling capabilities in ETIS for Maryland and Virginia.

3. Not all counties in the North Carolina HES are included in the current version of ETIS. The HES counties impacted by Hurricane Isabel that do not yet have full travel demand forecast capability in ETIS include Bertie, Camden, Chowan, Craven, Jones, Martin, Pasquotank, Perquimans, Tyrrell and Washington. Furthermore, these counties cannot be committed for evacuation in ETIS, so the program's function as a source for evacuation information is also limited. The addition of these counties will greatly improve the accuracy of the ETIS travel demand forecasts for North Carolina and provide more complete evacuation information to other users.

   Recommendation: Expedite the addition of travel demand modeling capabilities for all remaining coastal counties included in the North Carolina HES.

4. Currently, the ETIS program does not collect or display any real-time roadway status information during an actual evacuation event despite the measured proliferation of Intelligent Transportation System (ITS) equipment throughout the country. The development of a function in the program that automatically assimilates real-time traffic counter data during evacuations would significantly enhance the utility of the program. This capability is under development for the real time traffic counters in South Carolina, but the future work plan for ETIS does not yet include the same effort for any of the other hurricane prone states. During the post-storm surveys in North Carolina, Virginia and Maryland, emergency managers throughout expressed an interest in having access to real-time traffic volume and average speed data during evacuations. Given the need to manage the regional evacuation road network in all three states, the capability to access traffic status information in near real time would greatly improve traffic management, sheltering and public information operations.

   Recommendation: Advance the development of an automatic traffic counter data assimilation function into ETIS for all states that have real time capabilities.

5. Multiple user access is essential for the information exchange role of ETIS, but limits its function as an analysis tool since it cannot be used by emergency planners to assess the implications of different evacuation decisions or traffic management measures on the

roadways. To use ETIS as an analysis tool for testing various evacuation scenarios during a hurricane event will provide erroneous, albeit temporary, protective action information to the other users simultaneously accessing the program. With increasing NHMPP emphasis on traffic management in evacuation planning and implementation, the ability to develop and analyze the impacts of different courses of action would be very beneficial to decision making and other pre-landfall response operations. Therefore, a version of ETIS that can reside as a program on a computer hard drive without shared access to multiple outside agency users would allow state evacuation planners and other emergency response personnel to use ETIS as an analysis tool. This stand-alone capability would also be more suitable for developing evacuation scenarios for hurricane response exercises, as well as other evacuation and shelter operations training.

Recommendation: Develop a new component in ETIS that will allow evacuation planners at the state level to investigate the traffic impacts of various evacuation strategies or alternatives.

Chapter 8
Shelter Operations

The primary objectives of the shelter analyses prepared for the FEMA/USACE comprehensive hurricane evacuation studies are to list public shelter facilities, assess their vulnerability to storm surge and fresh water flooding and to estimate the number of people who seek public shelter for a particular hurricane intensity or threat. Shelter location and capacity data are obtained from state and local emergency management staff working in conjunction with the American Red Cross (ARC), school boards, as well as other state and local agencies. Comparisons are then made with SLOSH data to assess flooding potential for storm surge, as well as with the National Flood Insurance Program (NFIP) Flood Insurance Rate Maps (FIRMs) to determine their vulnerability to riverine, or other types of freshwater flooding. Capacities are normally based on a 15 to 20 square foot per person allocation using the footprint of a structure or rooms to be utilized as a public shelter. These shelter capacity figures are then related against the local communities' shelter demand figures generated in the transportation analysis to determine potential shelter deficits or surpluses. The shelter demand figures are derived from the behavioral analysis also performed as part of the comprehensive Hurricane Evacuation Study (HES) process. These in-community shelter figures are important in that a deficit forces residents who would normally seek public shelter within their communities to travel further to find a final safe destination. Shelter deficits can result in worse clearance times and greater traffic congestion.

Another factor which must be acknowledged in providing public shelters during hurricanes is determining whether the building is capable of withstanding high wind pressures and repeated strikes by flying projectiles, as well as other structural considerations. These structural issues required FEMA, USACE, the Environmental Protection Agency (EPA), the ARC, and Clemson University to develop a hurricane-specific set of shelter selection guidelines as a supplement to the ARC 3041, Mass Care: Preparedness and Operations, named the Standards for Hurricane Evacuation Shelter Selection, or ARC 4496. Currently, the ARC will not manage a shelter in a hurricane risk area unless the facility complies with the criteria in ARC 4496. Although there is an exemption process for facilities that may have extenuating circumstances relative to those criteria, many shelter facilities throughout the nation have been removed from local, state and ARC inventories for use during hurricanes. These more stringent requirements for hurricane shelters may also impose more requirements on the HES study process with respect to assessing shelters in hurricane vulnerable communities.

Shelter issues were discussed with state and local government officials to ascertain what actions relative to sheltering were undertaken during Hurricane Isabel. The responses to the surveys and the interviews conducted by the Post-Isabel Survey Team are included in Table 8-1 below. The interviews focused on the following topics:

- How many shelters were opened;
- How many people were sheltered and whether there was enough space for the shelter demand;
- The length that the shelters stayed open; and
- The operational and other problems experienced in the shelters.

The figures for how many shelters were opened and how many people were accommodated therein during Hurricane Isabel vary, but in all 11 states impacted by Hurricane Isabel, FEMA concluded that a total of 36,000 people were in 352 shelters at some point during the storm. In North Carolina, the ARC estimated that it opened 125 shelters and accommodated 24,138 evacuees during Isabel. The Hurricane Isabel Assessment Team for the Commonwealth of Virginia indicated that approximately 6,000 evacuees sought shelter in 134 facilities statewide at the height of the storm, while about 5,400 Maryland residents weathered the hurricane in over 50 shelters throughout the state.

Based on the interviews, many communities in all three states indicated they experienced a variety of sheltering problems, but most apparently were able to accommodate the evacuees from Hurricane Isabel. Of the 44 surveyed jurisdictions that opened shelters only nine provided any indication that their capacity was taxed during this storm, and three of those indicated that the community as a whole was sufficient, but that one facility was close to full. Table 8-1 below provides a summary of the Post-Isabel Survey responses by emergency managers and other local government officials.

Table 8-1. Summary of Survey Responses for Shelter Operations

Survey Community	Number of Shelters Opened / Managers	Estimated Number of People Sheltered	Shelters Sufficient For Storm Evac Demand	Length of Operation	Reported Problems Encountered
NORTH CAROLINA					
Beaufort Co.	3 – ARC	800 Shelterees Primarily form Hyde Co. and Outer Banks	Yes	48 Hours	Lack of Security; Shortage of Staff; Loss of Utilities
Bertie Co.	3 – ARC 2 – Faith Based	650 100	Yes	48 Hours	Flooding from rainwater entering structure; Overcrowding
Brunswick Co.	3 – ARC	300	Yes	24 Hours	No Problems
Camden Co. & Pasquotank Co.	1 – ARC	475 Shelterees Primarily form Outer Banks (Dare, Currituck, Camden Co.)	Yes	10 Days	Lack of Security; Shortage of Food; Almost to Capacity; Shortage of Supplies; Shortage of Staff; Loss of Utilities; Unanticipated Medical Issues
Carteret Co.	2 – ARC 1 – Special Needs 1 – Other	1,500 75 25	Yes	24 Hours	No Problems Reported
Chowan Co.	2 – ARC ~5 – Faith Based	450 300	Yes	No Information Provided	No Problems Reported
Craven Co.	4 – ARC ? – Special Needs [1] 15 – Faith Based	1,800 ~25 ?	Yes	1 ½ Days	Shortage of Staff
Currituck Co.	[2]	[2]	[2]	[2]	[2]
Dare Co.	[2]	[2]	[2]	[2]	[2]
Hyde Co. [3]	[2]	[2]	[2]	[2]	[2]
Jones Co.	3 – ARC	1,000	Yes	1 ½ Days	No Problems Reported
Martin Co.	3 – ARC	~ 1,000	Yes	3 Days	No Problems Reported
New Hanover Co.	1 – ARC	101	Yes	27 Hours	No Problems Reported

Survey Community	Number of Shelters Opened / Managers	Estimated Number of People Sheltered	Shelters Sufficient For Storm Evac Demand	Length of Operation	Reported Problems Encountered
NORTH CAROLINA (Continued)					
Onslow Co.	6 – ARC	800	Yes	2 Days	Lack of Security; Shortage of Trained Staff
Pamlico Co.	1 – ARC	380	No	18 Hours	Overcrowding; Loss Of Utilities – Generator Went Out
Pender Co.	3 – ARC	796	Yes (but reportedly close to being overloaded)	No Information Provided	Migrant Workers Bussed In From Adjacent Co.; Near Overcrowding
Perquimans Co.	1 – ARC	350	Yes	No Information Provided	Loss of Utilities (Power and Water)
Tyrell Co.	1 – ARC	4	Yes	6 Days	No Problems Reported
Washington Co.	2 – ARC 1 – Special Needs	192 20	No (kept for locals only)	3 Days	Shortage of Food
North Carolina Division of Emergency Managment	4	4	Overall Yes	4	4
VIRGINIA					
Accomack Co.	5 – ARC 4 – Faith Based 2 – Other	2,100 100 50	No (Need more space)	1 ½ Days	Location Confusion; Lack of Security; Shortage of Food; Overcrowding; Shortage of Shelters; Shortage of Supplies; Shortage of Staff; Loss of Utilities; Unanticipated Medical Issues
Chesapeake	7 – ARC	1,910	Yes	4 Days	Problems With Closing Due To Homeless Residents
Chincoteague	5	5	5	5	5
Gloucester Co.	2 – ARC 1 – Special Needs	500 25	Yes	10 Days	Unanticipated Medical Needs
Hampton	2 – ARC	1,500	Yes	2 Days	Shortage of Food; Overcrowding; Shortage of Supplies; Loss of Utilities

Survey Community	Number Of Shelters Opened / Managers	Estimated Number of People Sheltered	Shelters Sufficient For Storm Evac Demand	Length Of Operation	Reported Problems Encountered
		VIRGINIA (Continued)			
Isle of Wight Co.	2 – ARC	~325	Yes	72 Hours	Lack of Security; Loss of Utilities; Unanticipated Medical Issues; Generator Failure
Lancaster Co.	1 – ARC	350	No [6]	24 Hours	Lack Of Security; Overcrowding; Shortage Of Shelters; Shortage Of Supplies; Shortage Of Staff; Loss Of Utilities; Unanticipated Medical Issues; Churches As Refuges Opened
Mathews Co.	2 – DSS [7]	300	Yes	3 Days	Shortage of Food; Roof Partially Blown Off Shelter; Shortage of Supplies; Unanticipated Medical Issues
Newport News	10 – ARC 1 – Special Needs	1,640 35	Yes	No Information Provided	Shortage of Food; Minor Wind Damage; Loss of Utilities; Unanticipated Medical Issues
Norfolk	? – ARC [8]	1,250 [8]	[8]	[8]	[8]
Northumberland Co.	2 – ARC	410	No	1 Day	Lack of Security; Overcrowding; Shortage of Staff (Nurses); Opened School With No Generator; Shelterees from Tangier Is. Arrived Early
Poquoson [9]	1 – ARC	101	Yes	3 Days	Loss of Utilities
Portsmouth	1 – ARC	No Information Provided	Yes	No Information Provided	Loss of Utilities
Richmond Co.	1 – ARC	135	Yes	24 Hours	Turned Away Volunteers; Report of Prostitution
Suffolk	4 – ARC	515	Yes	3 Days	Loss of Utilities; Leak in Roof
Virginia Beach	10 – ARC	2,500	Yes	4 Days	Loss of Utilities; Unanticipated Medical Issues

Survey Community	Number Of Shelters Opened / Managers	Estimated Number Of People Sheltered	Shelters Sufficient For Storm Evac Demand	Length Of Operation	Reported Problems Encountered
VIRGINIA (Continued)					
Westmoreland Co.	1 – ARC 3 – DSS [7]	18 1,800 – 2,000	No (but received the maximum it could handle)	7 Days	Shortage of Food; Overcrowding; Shortage of Shelters; Shortage of Supplies; Shortage of Staff
York Co.	3 – ARC 1 – Faith Based 1 – Employee Shelter	441 0 20	Yes	36 Hours	Shortage of Staff; Loss of Utilities
Virginia Department of Emergency Management	[4]	[4]	[4]	[4]	[4]
MARYLAND					
Anne Arundel Co.	3 – ARC 1 – Faith Based (SA) 1 – Other	300 in all five shelters	Yes (although there was overcrowding in one)	7 Days	Overcrowding (in 1 shelter); Shortage of Supplies; Shortage of Staff; Loss of Utilities (in 1 shelter); Lack Of Cots; One Shelter Had to Relocate Due to Loss of Power
Baltimore Co.	ARC manages all shelter operations	Unknown	Yes	No Information Provided	No Information Provided
Baltimore City	4 – ARC 1 – For Homeless	97 34	Yes	4 Days	No Problems
Calvert Co.	3 – ARC	230	Yes	4 Days	Lack of Security Between Buildings; Shortage of Cots (Wrong Size, Not Enough); Loss of Utilities; Unanticipated Medical Issues; Shelter Mgmt. Inconsistent
Caroline Co. [10]	2	105	Yes	2 Days	No Information Provided

Survey Community	Number Of Shelters Opened / Managers	Estimated Number Of People Sheltered	Shelters Sufficient For Storm Evac Demand	Length Of Operation	Reported Problems Encountered
MARYLAND (Continued)					
Cecil Co. [10]	2	11	Yes	2 Days	No Information Provided
Charles Co.	3 – ARC	230	Yes	3 Days	Unanticipated Medical Issues (Sent to Extended Care); Generator Fire
Dorchester Co. [10]	2	201	Yes	5 Days	No Information Provided
Harford Co.	Used Hotels	12	Yes	Not Applicable	Shelter Staffing Shortfalls
Howard Co.	3 – ARC	3	Yes	No Information Provided	Lack of Security
Kent Co. [10]	2	150	Yes	3 Days	No Information Provided
Prince George's Co.	6 – ARC (and Co. Government)	50	Yes	1 Day	Shortage of Staff; Loss of Utilities
Queen Anne's Co. [10]	2	119	Yes	3 Days	No Information Provided
Somerset Co.	6 – Somerset Co., ARC,City of Crisfield, Salvation Army	732	Yes	18 Hours	More Translators (Spanish) Needed; Loss of Utilities; Generator Problems
St. Mary's Co.	4 – ARC (and Government Agencies)	728	Yes	7 Days	Loss of Utilities (Intermittent)
Talbot Co. [10]	2	78	Yes	4 Days	No Information Provided
Maryland Emergency Management Agency	[4]	[4]	Overall Yes	[4]	Statewide Shortage of Shelter Staff

1 Special needs patients taken to various health care facilities throughout the community.
2 No shelters opened in county, all evacuees sent out of county.

Additional footnotes on next page

3 Has specific sheltering mutual aid agreement with Beaufort Co.
4 See county data.
5 Reported with Accomack Co.
6 Arrangements were being made to open another secondary shelter.
7 Department of Social Services.
8 Information obtained from presentation, specific information not provided.
9 Poquoson shares a shelter with York Co
10 Information for these counties obtained from American Red Cross of the Delmarva Peninsula.

The following shelter issues and recommendations stem primarily from comments provided during the survey interviews with local governments. Hurricane Isabel did not cause any serious or widespread incidents with respect to the opening and sustaining of shelters during the event. Instead the storm exposed more generalized operational issues and concerns about the shelter programs within the surveyed communities. State and local governments generally reported that they experienced resource shortfalls and other operational problems, rather than program-related issues that can be directly addressed by National Hurricane Mitigation and Preparedness Program (NHMPP) products and services. Nonetheless several emergency managers in all three states expressed specific concerns about the viability of various aspects of their shelter programs in other hurricane scenarios. In that respect most of the recommendations below address the problems encountered during Isabel using a more policy-oriented or programmatic approach.

1. There are areas and regions throughout this nation where employing traditional evacuation strategies as the primary protective action for hurricanes is no longer a viable or safe option. More hurricane evacuation planners are realizing that a continued reliance on conventional evacuation as a response to an approaching hurricane threat may ultimately result in a major loss of life. Some major urbanized areas along the Atlantic coast, especially in the southeastern United States, will require evacuation lead times that can extend to two or more days before the arrival of tropical storm-force winds. The predominant reason is that population growth in many coastal communities far exceeds even the most ambitious road building programs in those areas, especially with respect to meeting evacuation travel demand. The evacuation situation has become so acute that there are regions that cannot safely evacuate in one full day even for hurricanes that are not considered major, i.e. category 3 and above.

   The traditional paradigm for evacuations during hurricane events is that residents and tourists who are directed to leave storm surge-vulnerable areas and mobile homes frequently will travel relatively great distances, to locations well outside their communities, to escape the threat or comply with local government directives. Further compounding the normal evacuation situation is the spontaneous evacuation of residents not in storm surge-vulnerable areas or mobile homes that elect to leave their communities, even in the absence of a specific order from local government officials to do so. These "shadow evacuees" can contribute significant amounts of additional traffic volume to already overburdened evacuation roadway networks. Consequently, a growing possibility for some hurricane-vulnerable coastal states is that for any storm, thousands of evacuees will be stranded in their vehicles as hurricane-force winds begin to impact them. An even more dangerous but no less probable outcome is that traffic queues will extend back to the coastal evacuation zones, trapping residents and visitors in areas subject to storm surge and waves.

Probably the most effective means of countering the worsening efficacy of the conventional evacuation strategy is to encourage the public in hurricane prone areas to evacuate as short a distance as possible, preferably within the jurisdiction. The shorter the evacuation distance, the less likely that converging and competing evacuation streams, especially at the regional level, will cause the types of traffic congestion and dangerous circumstances described above. If in-community sheltering is not possible or insufficient, then a coordinated plan where adjoining counties not subject to storm surge open their facilities for the benefit of hurricane refugees is an effective means to limiting evacuation distances. To that end, Maryland is currently working towards developing a host shelter plan to at least contain their evacuation traffic to a regional level. Clearly the Delmarva Peninsula would benefit greatly if most hurricane evacuees could find structurally sound shelter spaces within their region rather than attempting to reach the more distant and congested destinations of Philadelphia or the Baltimore/Washington metropolitan areas. Virginia is also considering such a measure to develop a coordinated host shelter plan.

Local governments in all three of the surveyed states and the State Emergency Management Agencies (EMAs) themselves expressed a significant degree of concern regarding a myriad of shelter issues, many of which could have major impacts on this nation's ability to effectively protect its citizens from tropical cyclones, especially major hurricanes. Among the problematic issues cited include: the need for comprehensive state and regional host shelter plans; deficiencies in shelter staff; local and regional shortfalls in the number of shelter facilities; the lack of confidence in the structural suitability of shelters during hurricane-force wind conditions; and the absence of guidance on the selection and use of refuges of last resort (ROLR).

Recommendation: Advocate and encourage in all hurricane-prone states the concept of sheltering evacuees locally as a better protective action for hurricanes than traditional evacuation strategies.

2. Local governments and state officials throughout the survey area for this post-storm effort, especially Maryland, expressed their concerns about the shortage of shelter managers and other staff to operate shelters during hurricanes. Although the ARC assumes much of the responsibility for operating hurricane shelters throughout the nation, sheltering is ultimately a community issue that rests on the shoulders of local officials. There are numerous public and private organizations, other than the American Red Cross (ARC), that can and have been employed to resolve shelter staffing issues. Among these are the Salvation Army and other charitable religious organizations; local and state health and welfare agencies;, state social services agencies; the U.S. military; and local school boards to name a few. Since many of these agencies rely primarily on volunteers, frequently from the areas to be evacuated, there is no assurance that they will be available to manage shelters and handle the other necessary staffing responsibilities, especially before landfall. Additionally, if the NHMPP is successful in increasing local and state shelter capacities and encouraging more local residents to use them, these staffing constraints will only get worse. The only reasonable method to address these shelter staffing and management issues is to solicit the involvement of other organizations that are ready and willing to assume the role and facilitate their participation. Implicit within this task is for the NHMPP to endorse and provide operational guidance to assist state and local governments in developing this alternate sheltering capability and implementing it during hurricane events.

   Recommendation: Provide state and local governments with the guidance needed to become self-sufficient in staffing their shelters during hurricanes.

3. The relatively high percentage of evacuees that stayed in their coastal communities during Isabel provides a strong rationale for increasing efforts to ensure the structural viability of public shelter facilities. In behavioral surveys conducted in Maryland for this post-storm assessment, 74 percent of the respondents that evacuated remained within their counties. It is likely that these high figures are a reflection of the relatively few evacuation orders issued for

this storm, and the fact that many evacuated at the last possible moment in hazardous conditions. Nonetheless, local emergency management officials did indicate that they believed a large number of their residents would elect to remain in their communities regardless of storm scenario.

Even in the coastal counties of North Carolina not including the Outer Banks, 37 percent of evacuees indicated that they did not leave their counties during Isabel. Nearly half the evacuees in the coastal communities of Virginia (47%), traveled to other locations within their jurisdictions. Unlike many evacuees in Maryland, residents in both of these states had evacuation orders in effect for their areas and had ample time to travel to destinations outside their own communities. Many of the respondents in North Carolina, Virginia and Maryland (30%, 32% and 26% respectively) cited concerns about being stranded on the road during an evacuation which may account for why so many remained within their counties or cities of origin during Hurricane Isabel.

Regardless of policy decisions by the hurricane community regarding the adoption of a local sheltering versus traditional evacuation strategy, the ARC has officially decreed that it will not manage any shelters in a hurricane risk area unless they comply with the Shelter Selection Guidelines in ARC 4496. These guidelines provide certain prescriptive structural and operational standards for public shelter facilities in order to be certified for use by the American Red Cross. The nation should expect no less of a structural certification than ARC 4496 for any shelter facility regardless of which public or private organization will manage it.

In some of the survey counties in all three states, emergency management indicated that they did not feel comfortable making a decision to use their local shelters, since they had no assurance that those facilities were indeed safe when subjected to hurricane-force winds or greater. In many cases they did anyway because the circumstances accompanying this particular storm gave them little choice; people were directed to evacuate, or spontaneously left at the last minute as the hazards created serious concerns for public safety. There was not enough time to conduct an evacuation, only to extract coastal residents in the midst of the hazards and put them in public shelters.

Furthermore, given the normal uncertainty associated with tropical cyclone forecasting, there is no assurance that a host shelter community initially not expected to be at risk for a particular hurricane, even well inland, will not eventually be subjected to hurricane-force or greater winds. Even shelter facilities one hundred or more miles inland may have their structural components tested by hurricane-force winds, wind-borne debris and projectiles, as well as other hazards that can compromise the integrity of a building's envelope. In light of these circumstances, all state and local governments would benefit greatly by having an available inventory of shelter facilities capable of withstanding hurricane winds and other related hazards.

In light of this objective, proactive steps can be undertaken by the NHMPP to assist state and local governments with identifying the needed shelter facilities and implementing operational plans to manage them. A reasonably user-friendly version of the prescriptive standards in ARC 4496 has already been developed and the HES development process can provide a perfect vehicle to conduct these structural surveys and document the results.

Recommendation: Encourage an increase in the inventory of ARC 4496-compliant shelters at the local and regional level for all states participating in the NHMPP.

4. An additional shelter issue voiced by numerous government officials in all three of the surveyed states is accommodating people with special needs. As the population of this nation continues to age, the need for specialized shelter facilities to protect them during hurricanes will grow. Currently there is no national policy or guidance that addresses hurricane shelters for populations with special needs (PSNs). The operational requirements for a PSN facility are normally much greater than for a general population shelter which frequently precludes the intermingling of both types of evacuees at one location. Furthermore, because of an internal policy which requires that they, with some caveats dealing with pets and firearms, must accept anyone that arrives at one of their shelters, the ARC will not manage a facility operated for PSNs exclusively. As a result, the burden for sheltering these special populations during a hurricane normally rests solely on the shoulders of state and local officials.

An all-too-frequent complication for many communities operating shelters during hurricane evacuations occurs when patients with very specialized medical requirements are deposited at general population or PSN shelters. Frequently these medically challenged clients arrive at a shelter without any prior notice, coordination, or needed life support equipment and supplies which further compounds the hardships imposed on local governments.

The lack of any national guidance regarding PSN sheltering is therefore a common complaint from almost any community in hurricane-prone states. Few resources exist which provide state and local governments with any operational or policy assistance in managing and operating PSN shelters during hurricanes. Consequently, many state and local governments have up to now primarily reacted to situations where they have had to deal with sheltering PSNs, rather than implement the procedures from a coordinated, pro-active plan. Although Maryland is currently considering the concept of regional special needs shelters, they will probably have to develop those plans without any direction or technical assistance.

Recommendation: Develop comprehensive guidance regarding the policies, operational requirements and resources needed to implement an effective populations with special needs (PSN) sheltering program at the state and local level.

Figure 8-1. Meeting with Local Officials from Tyrrell County, NC

Chapter 9

Public Information and Emergency Communications

Although not customarily included as a component of the comprehensive hurricane evacuation study (HES) process, public information is nonetheless recognized as an increasingly important aspect of hurricane preparedness and response operations. With the advent of technologies such as the Internet, Geographic Information Systems (GIS) and other methods to facilitate the movement of information, the products prepared as part of the HES should become more digital and technologically oriented. The National Hurricane Mitigation and Preparedness Program (NHMPP) is working toward developing HES products that are easy to interpret for the lay person during a hurricane and providing the assistance necessary to ensure that all governments send out a message that is clear, concise and pervasive.

In conducting interviews throughout the three states surveyed for the Post-Isabel Assessment, a recurring theme among local governments was the need for assistance in effectively communicating with the public, especially pre-landfall when information can have life and death implications for the recipient. Almost all jurisdictions have public information programs that are activated during emergencies, but many still request federal and state assistance in crafting their messages and improving the means to communicate with the populations within their communities and beyond. Table 9-1 summarizes the responses to the more salient questions regarding public communications and information. A synopsis of the conclusions, comments and specific requests is provided below:

Table 9-1. Summary of Survey Responses for Public Information

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
NORTH CAROLINA					
Beaufort Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Fax; Interview; Pamphlets and Brochures; E-Mail; Press Conference; Mass E-Mail Groups **Public:** TV; Radio; Fax; Interview; Press Releases	Nat'l Weather Service **(NWS)**; North Carolina Emergency Management **(NCEM)**; Nat'l Hurricane Center **(NHC)**	None Known	Lack of Hurricane and Event Information in Spanish
Bertie Co.	HURREVAC; Weather Channel; State Agencies; Local EMAs; Internet	**Media:** Telephone; Website; Fax; Interview; E-Mail; **Public:** TV; Radio; Website; Newspaper	Bertie Co Govt.; Weather Channel **(TWC)**; Nat'l Oceanographic and Atmospheric Admin **(NOAA)**	Info Not Provided	Info Not Provided
Brunswick Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview; Pamphlets and Brochures; E-Mail; Mass E-Mail Groups **Public:** Media; Website	NWS; TWC	Adjacent Co. Did Not Evacuate (Inconsistent Message to Public)	None Known
Camden Co. & Pasquotank Co.	Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs;	**Media:** Telephone; Fax; Interview; Pamphlets and Brochures **Public:** Press Releases; Flyers; Law Enforcement with PA System	NWS (Wakefield Weather)	Language Barriers with Spanish and Vietnamese	Evac Decision Info; Storm Info

Survey Community	Agencies and Products That Provided Event Info [1]	Means to Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
NORTH CAROLINA (Continued)					
Carteret Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview **Public:** Press Releases; Fax; Interview	NHC; Accuweather; NWS (Newport); Ocean Prediction Center	Population Apathy	Storm Info (Didn't Know Surge Would Be So High)
Chowan Co.	HURREVAC; Weather Channel; Commercial Media; Local WFOs; Internet	**Media:** Interview **Public:** Info Not Provided	Info Not Provided	Info Not Provided	Info Not Provided
Craven Co.	HURREVAC; State Agencies; Local WFOs	**Media:** Press Conference; Mass E-Mail Groups **Public:** Media	Not Applicable	None Known	None Known
Currituck Co.	HURREVAC; Weather Channel; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview; E-Mail; Press Conference; Mass E-Mail Groups **Public:** Local Media; Door to Door Bullhorn	NOAA EM Page; NOAA Home Page; NOAA GOES Sat. Page; Strominfo.net; hwn.org; NC Floodmaps; PC Weather Products; vortex.plymouth.edu	None Known	None Known
Dare Co.	HURREVAC; State Agencies; Commercial Media; Local WFOs; Internet; Hurrtrak	**Media:** Telephone; Website; Fax; Interview; Pamphlets and Brochures; E-Mail; Press Conference; Mass E-Mail Groups **Public:** Fax; Website; E-Mail; Press Conferences	NOAA; Multiple Sites	Info Not Provided	Info Not Provided

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info to Public	Type of Info That Public Had Problems Receiving From Local Govt.
NORTH CAROLINA (Continued)					
Hyde Co.	HURREVAC; Weather Channel; Commercial Media; Local WFOs; Internet	**Media:** Telephone; Fax; Interview **Public:** Radio; Reverse 911 (CAN); Newspaper	NOAA; NWS (Newport)	None Known	None Known
Jones Co.	HURREVAC; Weather Channel; Local WFOs; Internet	**Media:** PIO**;** Telephone **Public:** EAS Alert	NWS	Population Apathy (But Disseminating Info Went Very Well); Most News Media Concentrates on Needs of Large Cities	None Known
Martin Co.	HURREVAC; Weather Channel; Commercial Media; Local WFOs; Internet	**Media:** Fax; Interview **Public:** News Media, Fax; Interviews, Cable TV; Radio	NWS; NOAA; HURREVAC; NC Dept. of Transportation **(NC DOT)**	Info Not Provided	Info Not Provided
New Hanover Co.	HURREVAC; Weather Channel; State Agencies; Local WFOs; Adjacent Co. Shelter Offices	**Media:** PIO; Website; Fax; E-Mail; Joint; Information Center; PIO **Public:** PIO	Not Applicable	None Known	None Known
Onslow Co.	HURREVAC; Weather Channel; State Agencies; Local WFOs; Internet	**Media:** PIO; Telephone; Website; Video / Tape; Fax; Interview; E-Mail; Press Conference; Mass E-Mail Groups **Public:** PIO; Press Releases; Citizen Phone Band; TV Interviews	NWS; HURREVAC Download Site	Info Not Provided	Info Not Provided

Survey Community	Agencies and Products That Provided Event Info [1]	Means to Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
NORTH CAROLINA (Continued)					
Pamlico Co.	HURREVAC; Weather Channel; State Agencies; Local WFOs; Internet	**Media:** PIO; Telephone; Fax; Interview; **Public:** PIO	NWS (Newport); Storm Century	Population Apathy	Evac Decision Info; Storm Info (Intensity)
Pender Co.	HURREVAC; Weather Channel; Local WFOs	**Media:** Telephone; Fax **Public:** Co. EM Website; Press Releases in Several Large Cities to Help Absentee Property Owners; AM Transmitters with 5-Mile Range	NHC; FEMA For Recovery Info	No Problems In This Storm	None Known
Perquimans Co.	HURREVAC; Weather Channel; Local WFOs	**Media:** Telephone; Fax **Public:** Info Not Provided	Not Applicable	None Known	None Known
Tyrell Co.	HURREVAC; Weather Channel; State Agencies; Local WFOs	**Media:** Telephone; Fax; Press Conference **Public:** Radio; TV; Telephone; Newspaper	NWS; NOAA	Info Not Provided	Info Not Provided
Washington Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Internet	**Media:** Telephone; Fax; Interview **Public:** Reverse 911 (CAN)	NWS; NCEM	None Known	Many residents would not pick up phone on CAN Alert

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local govt. Problems Communicating Info to Public	Type of Info That Public Had Problems Receiving From Local Govt.
NORTH CAROLINA (Continued)					
North Carolina Division of Emergency Management	HURREVAC; State Agencies Including South Carolina; Local EMAs; Local WFOs	**Media:** PIO; Interview; News Releases **Public:** PIO; Governor Held 3 Press Conferences a Day	NWS; Unisys Weather	Media Doesn't Focus on Damage or the Risk	Info Not Provided
VIRGINIA					
Accomack Co.	HURREVAC; State Agencies; Local EMAs; Local WFOs	**Media:** Telephone with live feed into EOC; Fax; Interview **Public:** Radio and Other Media Outlets	Not Applicable	Info Not Provided	Info Not Provided
Chesapeake	HURREVAC; Weather Channel; State Agencies; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview; E-Mail; Press Conference **Public:** Press Releses to Media; Local Cable Channel; Local City Radio Station; Flyers; U.S. Postal Service Delivery to Households; Newspaper Inserts	VDOT; NWS; VDEM; NOAA	None Known	None Known
Chincoteague	HURREVAC; Weather Channel; State Agencies; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Fax; Interview **Public:** Radio; TV; Public Service Announcements	National Data Buoy Center (NOAA)	Population Apathy	None Known

Survey Community	Agencies and Products That Provided Event Info [1]	Means to Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
VIRGINIA (Continued)					
Gloucester Co.	HURREVAC; Weather Channel; State Agencies; Local EMAs; Local WFOs; Internet	**Media:** PIO; Telephone; Fax; Interview; E-Mails; Press Conference **Public:** PIO Using Same Methods As for Media	NOAA, Virginia Dept. Of Transportation **(VDOT)**; Virginia Department of Emergency Mgmt. **(VDEM)**; Accuweather for Radar Images	Information Too Complicated	Travel Time Estimates; Traffic Congestion Info.
Hampton	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview; E-Mails; Mass E-Mail Groups; Hand Delivery **Public:** 311 Call Center; Local Website; E-Mail; Local Media; Hand Delivered Flyers Throughout Neighborhoods	VDEM; NHC: Local Media; Local EOC	Not Enough Information; Local Media Focus Was Different; Power Went Down	Storm Information; Re-Entry Information; Information Disseminated by Media Not Necessarily Consistent with EM Message
Isle of Wight Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Fax; E-Mails; Telephone Conferences **Public:** Website; Press Releases	NWS; NOAA; Local Media; NHC	Not Enough Information (Poor Coverage by Major Media in Local Markets and Not Included In Any Scrolling TV messages); Loss of Power	Evacuation Decision Information; Evacuation Routes

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info to Public	Type of Info That Public Had Problems Receiving From Local Govt.
VIRGINIA (Continued)					
Lancaster Co.	HURREVAC; Weather Channel; State Agencies; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Fax (Done Regionally with Northumberland, Richmond and Westmoreland Co.); Interviews; E-Mail **Public:** Local Radio Stations and the Local EOC	VDEM; NOAA; NWS Wakefield	Population Apathy; Inadequate Infrastructure (Power Went Down)); Weekly Only Newspaper Limits Its Usefulness	All Information When Power and Radio Went Down
Mathews Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Fax; E-Mails **Public:** Telephone Fax to Radio Station for Broadcast Every Hour	NOAA; State Agency; TWC	Limited Means of Dissemination	Info Not Provided
Newport News	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet; Hurrtrak Tracking Program	**Media:** Telephone; Website; Fax; Interview; E-Mails; Mass E-Mail Groups; Hand Delivery **Public:** Website; Telephone; Local Cable Channel; PA System	NOAA; NWS (Wakefield); NHC; FEMA	Public Apathy, Not Concerned About Storm	Information Disseminated by Media Not Necessarily Consistent with EM Message
Norfolk [2]		PIO; rumor control; emergency website; provided all media with updated weather and safety info; responded to Media Inquiries			

Survey Community	Agencies and Products That Provided Event Info [1]	Means to Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
VIRGINIA (Continued)					
Northumberland Co.	HURREVAC; Weather Channel; State Agencies; EMAs; Local WFOs; Internet	**Media:** Telephone; Fax (Done Regionally with Lancaster, Richmond and Westmoreland Co.) **Public:** Regionally by Radio; Police Scanner Through Event to Give Out Info	NOAA; TWC; NHC; Intellicast	Population Apathy; Indigent Population in Region Doesn't Listen to Radio; Inadequate Infrastructure (Power Went Down); Weekly Only Newspaper Limits Its Usefulness	All Information When Power and Radio Went Down
Poquoson	Weather Channel; State Agencies; Commercial Media; Local WFOs	**Media:** Telephone; Interview; Press Conference **Public:** Local Cable Channel; Newspaper; Radio; PA System on Police and Fire Vehicles	Not Applicable	Population Apathy	Information Disseminated by Media Not Necessarily Consistent with EM Message
Portsmouth	HURREVAC; Weather Channel; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview; E-Mail; Press Conference **Public:** Media Release; Media Interviews; Websites; Radio; Flyers; U.S. Postal Service Delivery of Flyers; Newspaper Inserts	NOAA; TWC; Hurrtrak Tracking Program; VDOT; VDEM; Local Media; Richmond and Washington D.C. Papers	Info Not Provided	Info Not Provided

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info to Public	Type of Info That Public Had Problems Receiving From Local Govt.
VIRGINIA (Continued)					
Richmond Co.	HURREVAC; Weather Channel; State Agencies; EMAs; Local WFOs; Internet	**Media:** Telephone; Fax (Done Regionally with Lancaster, Northumberland and Westmoreland Co.) **Public:** Regionally by Radio	NOAA; TWC; NHC	Population Apathy; Indigent Population in Region Doesn't Listen to Radio; Inadequate Infrastructure (Power Went Down); Weekly Only Newspaper Limits Its Usefulness	All Information When Power and Radio Went Down
Suffolk	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs	**Media:** Telephone; Website; Fax; Interview; E-Mail; Press Conference **Public:** Media Release; Media Interviews; Personal Contact	NHC; NWS (Wakefield)	None Known	None Known
Virginia Beach	HURREVAC; Weather Channel; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Telephone; Website; Fax; Interview; E-Mail; Press Conference **Public:** Media Release; Media Interviews; Websites; Radio; Flyers; U.S. Postal Service Delivery of Flyers; Newspaper Inserts; Council Member Hand Out Info	NOAA; TWC; Hurrtrak; VDOT; VDEM; Local Media; Richmond and Washington D.C. Papers	Info Not Provided	Info Not Provided

Survey Community	Agencies and Products That Provided Event Info [1]	Means to Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
VIRGINIA (Continued)					
Westmoreland Co.	Weather Channel; State Agencies; EMAs; Local WFOs; Internet	**Media:** Telephone; Fax; (Done Regionally with Lancaster, Northumberland and Richmond Co.) **Public:** Regionally by Radio	NOAA; TWC; NHC	Population Apathy; Indigent Population in Region Doesn't Listen to Radio; Inadequate Infrastructure (Power Went Down); Weekly Only Newspaper Limits Its Usefulness	All Information When Power and Radio Went Down
York Co.	Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet; Hurrtrak Tracking Program	**Media:** Telephone; Website; Fax; Interview; E-Mails; Mass E-Mail Groups **Public:** Press Releases to Media; Local Cable Channel; PA System	NHC; NWS; VDEM (Wakefield); FEMA; PC Weather	Regional Media Ignores Smaller Jurisdictions Whose Residents Feel Uninformed	Not Aware of Any Problems
Virginia Department of Emergency Management	FEMA Regional Office; HURREVAC; Weather Channel; Other State Agencies (Especially DOT); HLT/ELT; Commercial Media; Local EMAs; Local WFOs; Internet; Private Weather Service	**Media:** Telephone; Website; Fax; Interview; Pamphlets and Brochures; E-Mails; Press Conferences; Mass E-Mail Groups; PSAs on Cassette Tapes **Public:** Same Means As The Media Plus Variable Message Signs And Local Radio	NHC; NWS (Wakefield); Weather Underground (for Model Data); HLT	None Known	None Known

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info to Public	Type of Info That Public Had Problems Receiving From Local Govt.
			MARYLAND		
Anne Arundel Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** PIO; Telephone; Fax; Interview **Public:** PIO; Rumor Control Line	NOAA; Weather Bug; TWC	Information Not timely; No Emergency/Rapid Means Of Notifying Public; No Reverse 911; Sirens Are Inoperable	Almost Any Information Was Difficult Since Most Victims Were Asleep As Hazards Made Evacuation Necessary
Baltimore Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet; EOC Reps	**Media:** Telephone; Interview; Press Conference **Public:** Radio; Website; PA System; Door to Door	NOAA; Any Site That Would Provide Info On Storm	Information Not Timely; Population Apathy; Loss of Power	Evacuation Decision Info
Baltimore City	Weather Channel; State Agencies; Local WFOs; Internet	**Media:** Mayor in EOC Directly Updating the Media in Press Conferences **Public:** Mayor Press Conferences and Faxes with Business Liaison Group	NWS	None Known	None Known
Calvert Co.	HURREVAC; Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** Website; Fax; Interview; E-Mail; Press Conference; Cable TV **Public:** Door to Door; Cable TV; Website; Fax and E-Mail (Code Red)	NOAA; Weather Bug; Nearby TV Affiliate	Loss Of Power Shut Down Radio Station And Caused EAS Station To Go To Alternate Frequency That Public Was Not Familiar With; Increased Reliance on Cordless and Cell Phones	All Information When Power and Radio Went Down

Survey Community	Agencies and Products That Provided Event Info [1]	Means to Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info To Public	Type Of Info That Public Had Problems Receiving From Local Govt.
MARYLAND (Continued)					
Charles Co.	HURREVAC; Weather Channel; State Agencies; HLT/ELT; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** PIO; Telephone; Website; Fax; Interview; Mass E-Mail Groups **Public:** PIO; Local Govt. Channel (Will Have For Future Events); Website; Local Media	NOAA: NWS; TWC; Mims (For Monitoring Hospital Status); County	Loss Of Power Shut Down Radio Station	Info Not Provided
Harford Co.	FEMA Regional Office; HURREVAC; Weather Channel; State Agencies; HLT/ELT; Commercial Media; Local EMAs; Local WFOs; Internet	**Media:** PIO; Telephone; Website; Fax; Interview; E-Mail; Press Conference; Mass E-Mail Groups; Rumor Control **Public:** PIO; Media Interviews; PSAs; Radio and Live Radio Interviews; Cable TV; Door to Door (After Storm)	NOAA; County; NexRad; Cable News; Nearby Major TV Station; Weather Bug; TWC	Info Not Provided	Info Not Provided
Howard Co.	Weather Channel; State Agencies; Commercial Media; Local WFOs; Internet; NAWAS	**Media:** PIO; Press Releases **Public:** PIO; County Website; Door to Door (Cadets Handing Out Pamphlets to Residents in Flood-Prone Areas)	NOAA; Weather.com; TWC	Info Not Provided	Info Not Provided

Survey Community	Agencies And Products That Provided Event Info [1]	Means To Distribute Info To The Media / Public	Websites Used To Access Storm And Event Information	Local Govt. Problems Communicating Info to Public	Type of Info That Public Had Problems Receiving From Local Govt.
MARYLAND (Continued)					
Prince George's Co.	Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet; NAWAS	**Media:** PIO; Press Conferences with County Executive; In Person Interviews in EOC with Radio, TV and Newspaper **Public:** PIO; Door to Door Info and Pamphlets	FEMA; NHC; NWS	Loss Of Power Shut Down Radio Station and Rendered Cordless and Cell Phones Inoperable	Info Not Provided
Somerset Co.	Info Not Provided	Info Not Provided	Info Not Provided	Info Not Provided	Info Not Provided
St. Mary's Co.	Weather Channel; State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet; NAWAS	**Media:** PIO; Fax **Public:** PIO; Fire Dept and Law Enforcement on PA system and Door to Door	Local and DC TV Channels; NOAA; TWC	Information Could Have Been More Timely; Loss Of Power Shut Down Radio Station And Caused EAS Station To Go To Alternate Frequency That Public Was Not Familiar With	All Information When Power and Radio Went Down
Maryland Emergency Management Agency	FEMA Regional Office; HURREVAC; Weather Channel; Other State Agencies; Commercial Media; Local EMAs; Local WFOs; Internet; Private Weather; Rumor Control; News Helicopters Good for Impact/Damage Assessment	**Media:** Telephone; Website; Video for Inland Flooding; Fax and Mass Fax; Pamphlets and Brochures; E-Mails; Press Conferences/ Video Conferences with EOC & Gov **Public:** PIO**;** FAQs on EMA Website; Public Statements	FEMA (Post-Event); TWC; NOAA; NHC (But Not HLT); Neighboring States; Not HLT	Surge and Tide Data Too Complicated for Public; Dealing with 4 Major Stations In 2 Major Media Markets	Surge / Wind Information and Protective Action Instructions

See Next Page For Footnotes

1 Among other agencies and resources that state and local governments indicated they generally used for information collection and dissemination: NASA; U.S. Coast Guard; Radio Stations; Newspapers; U.S. Postal Service; Church Organizations; HAM Radio Operators; Universities; Businesses; Chambers of Commerce; and Civic Leagues.

Below are the reported or observed issues raised by local and state experiences during Hurricane Isabel and the recommended actions to address them.

1. A significant number of local governments, especially rural ones on the fringe of larger urbanized media markets, experienced considerable difficulty in getting their emergency information out or competing with the needs of the larger jurisdictions. This is a common problem throughout hurricane vulnerable states. Television and radio stations frequently concentrate their data collection and dissemination efforts on the major city in their market areas, to the exclusion of smaller communities that also must rely on those media affiliates.

   It is not likely that this omission by the broadcast affiliates is intentional; nonetheless the public safety information needs of these smaller communities must be accommodated in these larger media markets. Therefore the NHMPP must undertake a concerted effort to develop a training program and the other means necessary to ensure that the emergency communication requirements of smaller local government are addressed in the major media markets. This effort should not only focus on training all local governments to develop effective measures for dealing with nearby media organizations, but also educate news managers and other broadcast affiliates staff about integrating their operations with every community's public safety information needs during disasters.

   Recommendation: Develop a comprehensive training and education program for communities and media organizations alike regarding better methods for integrating their public information operations during hurricanes and other disasters.

2. In surveys in the three most impacted states, almost every local government relied on websites to collect the necessary information to make hurricane protective action and response decisions. More than HURREVAC, websites during Hurricane Isabel were a universally exploited resource by emergency management for needed information, especially before the storm, when power was still available.

   Recommendation: Develop a one-stop comprehensive information webpage that assists state and local government representatives in readily gathering all

information that specifically relates to hurricane hazards or the overall event.

The web page could be password protected, and include a hyperlink to every possible useful webpage for emergency management purposes and activities. The Evacuation Transportation Information System (ETIS) Home Page (www.fhwaetis.com) is a simplified version of this concept in that all related information is aggregated and readily available from one server location. This website would not only make available the obvious hurricane related sites, but also provide ready access to river gauge, sea buoy, meteorological research, various 511 and other traffic monitoring websites, as well as a whole host of other Internet-based information sources. Even routine NHMPP information could be posted and made available for any appropriate and interested party to access.

3. A significant number of jurisdictions in the Post-Isabel Assessment surveys indicated communications issues with large, foreign-speaking populations. Communities in all three states experienced situations were non-English speaking people created operational issues with respect to evacuation, sheltering and recovery during the event. In these surveyed communities, as well as in almost every other one in the nation, foreign language-speaking populations are growing rapidly. Consequently there were a significant number of requests for assistance in developing all types of materials and media in foreign languages, including signage, forms and public service announcements that can be used to communicate effectively with these populations.

   Recommendation: Provide assistance to state and local governments in preparing hurricane-specific information in various media to effectively communicate with ethnic populations.

Appendix A

Meeting Attendees / Persons Providing Input

HURRICANE ISABEL
MEETING PARTICIPANTS
2003

NORTH CAROLINA

Name	Organization
Brock Long	FEMA, Region IV
Henrietta Alleman	FEMA
William Winn	FEMA
Billy Wagner	FEMA
Chris Mack	U.S. Army Corps of Engineers
Allan McDuffie	U.S. Army Corps of Engineers
Rodger Menzies	U.S. Army Corps of Engineers
Mark Brown	North Carolina Division of Emergency Management
Doug Haas	North Carolina Division of Emergency Management
David Humphrey	North Carolina Division of Emergency Management
Ed Jenkins	North Carolina Division of Emergency Management
George Sullivan	North Carolina Division of Emergency Management
Ron Wall	North Carolina Division of Emergency Management
Daden Wolfe	Beaufort Co. Emergency Management
Brian Watts	Brunswick Co. Emergency Medical Services
Scott Garner	Brunswick Co. Emergency Management
Randy Thompson	Brunswick Co. Emergency Services
Patrick Morton	Brunswick Co. Technical Services
Christy Saunders	Pasquotank and Camden Co. Emergency Management
Joanne Smith	Carteret Co. Emergency Management
Mike Addertion	Carteret Co. Emergency Management
Anne Marie Knighter	Chowan Co. Emergency Management
Stanley Kite	Craven Co. Emergency Management
Stanley D. Griggs	Currituck Co. Emergency Management
Liz S. Hodgis	Currituck Co. Emergency Management
Mary Beth Newns	Currituck Co. Emergency Management
Becky Sharber	Currituck Co. Emergency Medical Services
Kathlyn S. Romm	Currituck Co. Department of Social Services
Sandra Hill	Currituck Co. Finance
James Mims	Currituck Co. Fire Prevention
Dan Scanlon	Currituck Co. Manager
Nathaniel Sanderson	Dare Co. Emergency Management
Dean Burbage	Hyde Co.
Carol Tyndall	Jones Co. Emergency Management
Bill Silverthorne	Martin Co. Emergency Management
James Peele	Martin Co. Fire Chief
Marion Thompson	Martin Co. Payroll Officer
Donnie Pittman	Martin Co. Manager

HURRICANE ISABEL
MEETING PARTICIPANTS
December 2003

NORTH CAROLINA (Continued)

Name	Organization
Warren Lee	New Hanover Co. Emergency Management
Ray Church	New Hanover Co. Emergency Management
Carol Thiel	New Hanover Co. Emergency Management
Kristen Wingenroth	New Hanover Co. Emergency Management
Dottie Spruill	New Hanover Co. Grants Manager
Bruce Shell	New Hanover Co. Finance
Andre R. Mallette	New Hanover Co. Human Resources
David Stevenson	New Hanover Co. Sheriff's Office
Ruth Haas	New Hanover Co. Museum Director
David Ride	New Hanover Co. Health Department
Bruce Clontz	New Hanover Co. Information Technology Director
Patricia A Melvin	New Hanover Co. Manager's Office
LaVaugh Nesmith	New Hanover Co. Department of Social Services
Reid Hawkins	National Weather Service Office
Calvin Peck	Carolina Beach Town Manager
Sterling Powell	Wrightsville Beach Fire Department
Steve Conrad	Onslow Co. Emergency Services
Mark Goodman *****	Onslow Co. Emergency Services
David Spruill	Pamlico Co. Emergency Management
Eddie King	Pender Co. Emergency Management
Harry Winslow Jr.	Perquimans Co. Emergency Management
Bobby Darden	Perquimans Co.
J.D. Brickhouse	Tyrrell Co. Administration
Thomas Wall	Tyrrell Co. Emergency Management
Anne Keyes	Washington Co. Emergency Management
Jason Phelps	Washington Co. Sheriff's Office
Lyman Mayo	Washington Co.
Jerry Phelps	Washington Co. Emergency Medical Services
Joanne Bouquet	Washington Co. Assistant Town Manager
John Floyd	Washington Co. Fire Chief

***** Did not attend meeting, but did fill out Hurricane Isabel Response Questionnaire

HURRICANE ISABEL
MEETING PARTICIPANTS
March – April 2004

VIRGINIA

Name	Organization
Bob Shapiro	FEMA, Region III
Henrietta Alleman	FEMA
Joe Gavin	U.S. Army Corps of Engineers
Paul Moye	U.S. Army Corps of Engineers
Stewart Baker	Virginia Department of Emergency Management
Wallace Twigg	Virginia Department of Emergency Management
Michael Cline	Virginia Department of Emergency Management
Anthony Mclean	Virginia Department of Emergency Management
Harry Colestock	Virginia Department of Emergency Management
James Mock	Virginia Department of Transportation
Richard Childress	Isle of Wight Co. Emergency Management
Mark Marchbank	Virginia Beach Emergency Management
Jim Judkins	City of Suffolk Emergency Management
Brian Spicer	City of Portsmouth Emergency Management
Steve Best	City of Chesapeake Emergency Management
Hui-Shan Walker	City of Chesapeake Emergency Management
Jason Loftus	Accomack Co. Public Safety
Bryan Rush	Town of Chincoteague
Jim West	Town of Chincoteague
Jack White	City of Poquoson
Bert Geddy	City of Williamsburg
Buz Weller	City of Williamsburg
Judi Riutort	York Co. Emergency Management
Jack Williamson	City of Newport News Emergency Management
Donna Briede	City of Newport News Emergency Management
Emily Seward	City of Newport News Emergency Management
Pete Sommer	City of Hampton Emergency Management
Jim Redick	City of Hampton Emergency Management
Tracy Proctor	Gloucester Co.
Tim Doss *****	Gloucester Co.
Jerry W. Davis	Northern Neck Planning District Commission
Scott Hudson	Lancaster Co.
Bill Pennell	Lancaster Co.
Kenny Eades	Northumberland Co.
Bill Duncanson	Richmond Co.
Norm Risavi	Westmoreland Co.
Steve Whiteway	Mathews Co.
Tina George *****	WNIS - Norfolk
Deanna Malone *****	WRVA - Richmond
Jim Farley *****	WTOP - Washington, D.C.

HURRICANE ISABEL
MEETING PARTICIPANTS
March – April 2004

VIRGINIA (Continued)

Name	**Organization**
Robert Hughes *****	WTVR-TV - Richmond
Unknown *****	Richmond Times Dispatch
Terry Scanlon *****	Daily Press
Don Lewis	Post, Buckley, Schuh and Jernigan
Bob Collins	Post, Buckley, Schuh and Jernigan

***** Did not attend meeting, but did fill out Hurricane Isabel Response Questionnaire

HURRICANE ISABEL
MEETING PARTICIPANTS
March – April 2004

MARYLAND

Name	Organization
Bob Shapiro	FEMA, Region III
Henrietta Alleman	FEMA
Kara Deutsch	U.S. Army Corps of Engineers
Maria Hammond	U.S. Army Corps of Engineers
Robert Ward	Maryland Emergency Management Agency
Steve Welzant	Maryland Emergency Management Agency
Bill Talbott	Maryland Emergency Management Agency
Lauren Holley Allen	Maryland Emergency Management Agency
Theresa Chapman	Maryland Emergency Management Agency
Gary Harrity	Maryland Emergency Management Agency
Sharon Osborn	Maryland Emergency Management Agency
Laken Oyedokun	Maryland Emergency Management Agency
Carl Phelps	Maryland Emergency Management Agency
Kimberly Golden	Maryland Emergency Management Agency
Clint Pipkin	Maryland Emergency Management Agency
Fred Frey	Maryland Emergency Management Agency
Quentin Banks	Maryland Emergency Management Agency
Ed McDonough	Maryland Emergency Management Agency
James Weed	Anne Arundel Emergency Management
Michael O'Connell	Anne Arundel Emergency Management
Cathy Close	Anne Arundel Emergency Management
Steve Taylor	Anne Arundel Emergency Management
Tom Vidmer	Baltimore Co. Emergency Management
June Utter	Baltimore Co. Emergency Management
Jimmy Artis	Baltimore Co. Emergency Management
Dave Thomas	Baltimore Co. Public Works
Richard McKoy	Baltimore City Emergency Management
Bill Ballard	Baltimore City Office of Information Technology
Olivia Farrow	Baltimore City Health Department
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HURRICANE ISABEL
MEETING PARTICIPANTS
March – April 2004

MARYLAND (Continued)

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Joanna Snow	Charles Co. Animal Shelter
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Appendix B

Comparison of Observed SLOSH/Tide Model Computed Storm Tide for Hurricane Isabel (2003) in North Carolina, Virginia, Maryland and the Delaware Bay and River

COMPARISON OF OBSERVED AND SLOSH/TIDE MODEL COMPUTED STORM TIDE FOR HURRICANE ISABEL (2003) IN NORTH CAROLINA, VIRGINIA, MARYLAND AND THE DELAWARE BAY AND RIVER

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OCTOBER 2004

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1. INTRODUCTION

The U. S. Army Corps of Engineers, Office of Homeland Security/Federal Emergency Management Agency (OHS/FEMA) and the National Oceanographic and Atmospheric Administration/National Weather Service (NOAA/NWS) are extensively involved in determining the areas that are prone to flooding by hurricane storm surge along the U.S. Atlantic and Gulf of Mexico coastlines. Determination of areas prone to storm surge flooding is an essential prerequisite to evacuation planning.

Flood potential could be specified through a study of past events if, for the region of interest, a horizontal network of meteorological (pressure and wind) and hydrographic (tide gage) sensors had continuously recorded data during hundreds of historic hurricanes of varying intensity, direction and forward speed. In reality, hurricanes are very rare events for any region along the Atlantic and Gulf coastlines. Also, in the historical cases that do exist, many of the meteorological and hydrographic sensors failed during passage of the hurricane. Thus, for most of the U.S. coastline, the climatology of hurricane storm surge flooding is very limited.

To compensate for this lack of historical data, the NOAA/NWS developed a numerical storm surge model termed SLOSH (Sea, Lake, and Overland Surges from Hurricanes), Jelesnianski, et al (1992). The SLOSH model, given hurricane input parameters, computes storm surge heights over a geographic area that is covered by a mesh of computational grid points. This network, or model domain, is called a basin. At present, 35 basins cover the U.S. Atlantic and Gulf of Mexico flood plains. The basin that covers the flood plain of Eastern North Carolina has been designated the Pamlico Sound basin. The Chesapeake Bay basin covers the flood plains of Virginia, Maryland and Delaware.

Hurricane evacuation studies have been completed for these two basins. In each of these studies a series of hypothetical hurricanes of varying intensity, direction and forward speed, based upon historical records, has been simulated using the SLOSH model in each of the basins. The storm surge data generated by the SLOSH model simulations determines the flood-prone regions. With this knowledge, evacuation plans have been formulated for future use. During an evacuation study, historical hurricanes were also simulated with the SLOSH model. The comparison of the SLOSH model storm surge values and the observed storm surge values determine the confidence in the model (Jarvinen and Lawrence, 1985). Unfortunately, in both basins, simultaneous observations of both the storm surge and hurricane meteorological parameters for historical hurricanes have been almost nonexistent. For example, the last major hurricane to affect all of the Chesapeake Bay area was the 1933 hurricane. Limited meteorological data were obtained at a few observing sites situated around the Bay but no data was obtained at over-the-water observing sites in the Bay. Also, high water survey data were limited to the southern part of the Chesapeake Bay and only a few tide gage readings were available in the north part of the Bay. However, during the 2003 hurricane season, Isabel presented an opportunity for a comparison in these two basins. The purpose of this paper is a comparison of observed high water mark data versus SLOSH/Tide model computed values as well as a comparison of observed tide station hydrographs and SLOSH calculated hydrographs for both of the basins for hurricane Isabel.

2. PAMILICO SOUND AND CHESAPEAKE BAY SLOSH BASINS

The Chesapeake Bay basin grid, which covers the states of Virginia, Maryland and Delaware, is shown in Figure 1a. The grid is a telescoping polar coordinate system with 79 arcs and 84 radials. Similarly, but with a different mathematical coordinate system, the Pamlico Sound basin grid, which covers Eastern North Carolina, is shown in Figure 1b. The grid is a telescoping elliptical coordinate system with 180 arcs and 130 radials. Unlike typical coordinate grids, which would have a radial increment that was invariant with radius, these grids use a radial increment that increases with increasing distance from the grid's pole. The result is that, in each cell of the computational grid, the radial increment of the square is approximately equal to its arc length.

The two telescoping grids are a compromise. It is desired that a large geographical area with small detailed topography be modeled. In the Cartesian coordinate system, this combination of large area and spatially small grid increments requires a computational grid with many cells. A large computational grid requires a computer with a large central processing unit as well as time to perform calculations in the numerous grid squares. The telescoping grids, by comparison, resolve this conflicting needs: it has an acceptably small spatial resolution over land which is the area of the greatest interest. Thus, topographic details, such as highway and railroad embankments and dikes in harbors of cities, are included in the model. However, the range increment contained in each grid square becomes progressively larger with increasing distance from the pole. As a result, a large geographic area is included in the model, and the effects of the model's boundaries on the dynamics of the storm surge are diminished.

Thus, for the Chesapeake Bay basin, the small grid increments allow for good resolution of the bay itself as well as the rivers that flow into the Bay. Similarly, in the Pamlico Sound basin the small grid increments allow good resolution of the Pamlico and Albemarle Sounds including the rivers that flow into them.

3. SLOSH MODEL AND HURRICANE INPUT PARAMETERS

The SLOSH model's governing equations are those given by Jelesnianski (1967), plus a finite amplitude effect. Coefficients for surface drag, eddy viscosity and bottom slip are given by Jelesnianski (1972). There is no calibration or tuning to force agreement between observed and computed surges; coefficients are fixed and do not vary from one geographical region to another.

Special techniques are incorporated to model two-dimensional inland inundation, routing of surges inland when barriers are over-topped, the effect of trees, the movement of surge up rivers, and flow through channels and cuts and over submerged sills.

The SLOSH model requires hurricane input parameters at specified time intervals. These parameters include the latitude and longitude of the storm center, the atmosphere sea-level pressure in the center, and the radius of the maximum surface wind speed (RMW).

4. METEOROLOGY:

4.1 Track

Figure 2 shows hurricane Isabel's track with positions marked every 12 h at 0000 and 1200 UTC (see legend). After forming in the Cape Verde region on September 6, Isabel moved generally in a west-northwest direction for 9 days. During this time Isabel strengthened to a Category 5 hurricane on the Saffir/Simpson scale with a maximum wind speed of 165 mph. On September 15, the hurricane turned toward the north-northwest and began to weaken. Isabel maintained this direction with a gradual increase in forward speed until well after landfall in North Carolina. Isabel became extratropical on 19 September at 1200 UTC in western Pennsylvania where it turned to a more northerly direction and moved into Canada where it was absorbed into a larger low pressure system on the 20th.

Figure 3 shows hourly center locations of Isabel starting several hours before landfall in North Carolina and ending in western Pennsylvania. The hourly locations are labeled by three values separated by slashes. The first value is UTC. The second value is the central sea-level pressure in millibars. The final value is the RMW in statute miles. For example, 1100 /970/52 means 1100 UTC, 970 mb central sea-level pressure, and a radius of maximum wind of 52 statute miles.

The hourly center locations were obtained by a two-dimensional isobaric analysis using all available surface pressure observations which included land stations, offshore light towers, ships of opportunity and locations of minimum central sea-level pressure as observed by reconnaissance aircraft. Three hourly analyses after landfall, with the observations, including wind speed and direction, are shown in Figure 4a, 4b and 4c.

4.2 Intensity and Radius of Maximum Wind (RMW)

The lowest central sea-level pressure values in hurricane Isabel are shown for selected times in Figure 2. Isabel's lowest pressure of 915 mb occurred on 11 September at 1800 UTC. By the time Isabel made landfall at Drum Inlet, North Carolina the pressure had risen to 957 mb with a maximum wind speed of 105 mph, or a category 2 hurricane on the Saffir/Simpson scale. Even as a category 5 hurricane in the mid-Atlantic Isabel had a large eye and large RMW. As Isabel made landfall in North Carolina the RMW was estimated to be 52 st mi. The hourly central sea-level pressure values and RMW are shown in Figure 3. Of interesting note is the decrease in pressure but increase of the RMW as the system moves into northern Virginia, eastern West Virginia and western Pennsylvania. This very large size has not been observed in other historical hurricanes in this region. This large size produced a large wind field of tropical storm force winds with a long fetch over the Chesapeake Bay as shown in Figure 4c. This in turn helped to produce large storm tide values at the northern end of Chesapeake Bay and the upper reaches of the Delaware Bay.

4.3 SLOSH Model Run

Using the data shown in Figure 3 a SLOSH model run was made in both the Pamlico Sound and the Chesapeake bay basins. Comparisons of the SLOSH results with observed high water mark data (see section 5.1) in Pamlico Sound and the lower part of Chesapeake Bay showed typical results. However, the comparison in the upper or northern part of the bay showed the SLOSH values as being much too low. This suggested that the model wind speeds were too low and this in turn suggested that the model input parameters for this part of the SLOSH basin would not generate the observed wind. To compensate for this in the SLOSH model, the track and RMW remained the same but the pressure was adjusted so that the storm surge observed at Baltimore Harbor and Anapolis, Maryland were very close to the SLOSH calculated values. This compensation resulted in increased wind speeds which were slightly higher than the observed wind data in Baltimore Harbor (see next section).

4.4 Observed Surface Wind Profiles Over Water

Three locations in the region recorded wind data over water that are co-located with tide gages. These locations are unique because most wind recording sites are located inland and have frictionally modified winds. These locations are the eastern end of the Duck pier, the Chesapeake Bay Bridge Tunnel (CBBT) and the Francis Scott Key Bridge (FSKB) over Baltimore Harbor.

The anemometers at the three sites were at different heights. The Duck pier and the CBBT site had their anemometers close enough to the standard 10 meter elevation above mean sea level that no adjustment was made to the wind speeds. The FSKB site is located on the bridge at an altitude of 275 feet above mean sea level. The winds from this site were reduced to the 10 meter level by a logarithmic wind profile formula. For example, the observed wind maximum at 275 feet of a one-minute sustained wind of 76 mph (with a gust to 90 mph) was reduced to 62 mph at the 10 meter level. The plots of the wind speed versus time are shown in figures 5 a, b and c. The figure for the Duck pier also includes the wind direction. Wind direction values at the other two sites were not available. Also plotted in each figure is the one-minute sustained wind speed from the SLOSH model for that site. This is the wind speed used in the model (along with a direction) to calculate the wind stress terms that drive the water. The comparisons are reasonable but a bias can be seen in the SLOSH model calculated wind near the maximum observed values. The SLOSH model is over calculating the wind speed by about 8 to11 mph when compared to the observed.

Of interest in the observed data is the decrease of the wind speed maximum that occurred as one moves from Duck (79 mph) to CBBT (73 mph) to FSKB (62 mph). Intuitively, this is what one would expect for a system moving inland and weakening. However, the wind blowing at the FSKB site in Baltimore Harbor is much higher than calculated by wind decay models(i.e. 46 mph) and by observations at nearby inland sites. For example, the maximum wind observed at an inland site near Baltimore Harbor was at the Baltimore International Airport (BWI) with a one-minute sustained wind of 44 mph and a gust to 55 mph. Graham and Hudson (1960) compared the winds at the Baltimore Harbor Airport and the Baltimore Weather Bureau Office (BWBO) near downtown Baltimore for different wind directions at low wind speed conditions using hourly averages. For the southeast direction the ratio of BWBO's wind to the location used for the bay was found to be 0.64. In other words, the wind at BWBO should be increased by 1.56 to get a wind that would be observed in the harbor that was blowing from the southeast. We assumed that we could use this same ratio for BWI and the FSKB and that it would apply to one-minute averages and at high wind conditions. In the above example, using 44 mph from BWI gives 69 mph at FSKB. This further supports the 62 mph surface wind speed that was calculated from the FSKB wind data mentioned above.

Another source of "snap shot" wind data is aircraft reconnaissance (recon). During the time of landfall an aircraft recon flight flew approximately parallel and near the coastline and recorded wind information at an altitude of 7600 feet (see figure 6). The wind observations, in knots, are plotted every 2 minutes and labeled in UTC . Also located in figure 6 are the locations of Duck (FRF), CBBT, Cape Hatteras and the Maryland/Virginia border (M/V) on the Delmarva Peninsula. The aircraft observation that is closest to Duck is 1714 UTC and is 95 knots (109 mph)/130 degrees. The reduction factor down to the 10 meter surface elevation is 0.75 which gives 82 mph / 130 degrees. This can be compared to the observed value of 79 mph / 122 degrees at 1920 UTC. At CBBT the aircraft observation used for comparison was 1724 UTC or 85 knots (98 mph). Reduced to the surface by 0.75 gives 73 mph identical to the observed value of 73 mph. At Cape Hatteras the maximum flight level wind of 118 kts (136 mph) / 162 degrees was recorded at 1707 UTC. If we also use the reduction factor of 0.75 we get a surface wind speed of 102 mph. The SLOSH model maximum wind at this location is 101 mph at 1700 UTC. Finally, the wind speed value at M/V from recon is 75 knots (86 mph) at 1742 UTC or a surface value of 65 mph. The SLOSH model value at this location is 64 mph. The recon did not go any farther north so one is left to extrapolate the wind speed profile toward the north. Without to much imagination one could advect this aircraft profile along the track of Isabel and realize that the observed wind speed at the FSKB is very realistic especially considering the size of Isabel. This could happen even though the storm is continually filling after landfall, at least near the center.

5. HYDROLOGY

5.1 High Water Marks and Reference Datum

Under an OHS/FEMA requirement, post Isabel high water mark surveys were conducted in North Carolina, Virginia and Maryland. The survey teams were instructed to obtain as many "still water marks" as possible. Still water marks generally reflect the storm tide elevation without the effect of waves. However, because of time delays and the resultant post Isabel clean-up efforts many of these marks were lost. As a result "debris line" elevations, which generally are taken on the outside of buildings or where debris piles have been created by the rise in water, were obtained when a still water mark could not. Debris line elevations are generally higher than high water marks because of waves. About 70 percent of the high water marks are debris line observations. Figure 7a shows the location of these marks for the state of North Carolina and Figure 7b for the states of Virginia and Maryland. A total of 454 high water marks (received via personal communication with Mr. Bob Shapiro OHS/FEMA Region II) are shown on these figures. Overall the coverage of the high water marks is very good with many of them being located in the sections of the rivers where some of the highest storm tide occurred. NOTE: Some marks in the original data set were taken very far "up river" and well inland and represent fresh water flooding due to rainfall. These marks were not included in the data set or our figures.

The reference datum used for the high water marks in this study is the National Geodetic Vertical Datum of 1929 or NGVD29. This is where sea-level was in 1929 and this was the "zero" elevation. Since 1929 the tide gages along the Atlantic seaboard and inside of Chesapeake Bay have indicated a rise in sea-level on the average of about 0.75 feet. Thus, if a structure has a floor elevation of 10.0 feet above NGVD29 it is really 9.25 feet above the current day sea-level. The NGVD29 vertical datum is used for three main reasons. One, this has and still is the datum used for many buildings. Two, the SLOSH model uses this as the reference datum for all of its land elevations, bottom depths and calculated water elevations. (NOTE: In the structure mentioned above, if the SLOSH model calculated a value of 12.0 feet above NGVD29 in a grid square that the structure is located in, how much water would there be in the house? The answer is two feet.) Three, the water elevations taken after the 1933 hurricane and other historical hurricanes also reference NGVD29. To take the rise in sea-level into account for the high water marks, all of the Isabel SLOSH model simulations will include 0.75 feet in their initial water elevations.

5.2 Astronomical Tide and Initial SLOSH Model Elevations

As hurricane Isabel made landfall in North Carolina and continued into Virginia the daily astronomical tide was approaching high tide. In most instances peak storm surge occurred near the time of high astronomical tide for all of the North Carolina outer coast and most of southern Chesapeake Bay. For the outer coasts (i.e. Atlantic coasts) of both the Pamlico Sound and Chesapeake Bay basins the value used to simulate this high tide was 1.65 feet. For the inside of Chesapeake Bay the value was set at 1.25 feet. Although the peak storm surge began to get out of phase with the high tide in the northern part of the Chesapeake Bay the tide elevations were only slightly less than the southern portion and thus the 1.25 foot value for the high tide elevation could be used. Since the SLOSH models reference datum is NGVD29 we add 0.75 feet (see section 5.1) plus the 1.65 feet for high tide on the outer coast/ 1.25 feet inside Chesapeake Bay to the current day mean sea level to give 2.40 feet/ 2.0 feet above NGVD29 as the initial water elevations for the SLOSH model runs. Note: Pamlico and Albemarle Sounds in North Carolina have almost no tidal signal so the initial elevation for the Sounds was determined by tide gage readings before the hurricane arrived. This value was 1.0 feet above NGVD29.

5.3 Comparison of Observed High Water Marks to SLOSH/Tide Values

SLOSH model runs were made in both basins. The maximum SLOSH/Tide calculated value in a particular grid cell was compared to the observed high water mark located in the same cell. A scatter diagram was created for all of the marks and is shown in Figure 8. If the SLOSH/Tide calculated and observed are the same they will fall on the 45 degree line. As can be seen in the Figure 8 many of the observed values are much larger than SLOSH/Tide calculated. All of these observations have a wave component added to the storm tide value. This was mentioned as a possibility in section 5.1. In the comments section of each of the observed high water marks the survey team indicated if the mark might contain a wave component. We re-investigated all of the observed high water marks and removed all that contained contributions by waves. This reduced the number of observations from 454 to 397. Another scatter diagram with these values is shown in Figure 9 and the dramatic improvement in the results is evident.

Finally, the 397 pairs of values were subtracted from each other (i.e. SLOSH/tide minus observed) and a bar graph of the differences was created and is shown in Figure 10. The error characteristics are indicated in the legend. Eighty (80) percent of the differences fall between plus 1.5 to minus 1.5 feet while 96 percent are in the range plus 2.5 to minus 2.5 feet.

5.4 Comparison of Tide Gage and SLOSH Storm Surge Hydrographs

Hydrographic records from 27 tide or river gages in the region of Isabel's impact were obtained. Most of the tide gage data came from the National Ocean Survey (Hovis, et al, 2004). Figure 7a shows the locations and names of the gages in North Carolina and Figure 7b shows the locations in Virginia, Maryland, Delaware and Pennsylvania. Some of the records are incomplete because of a malfunction or loss of the gage. The hydrographs from these gages are also shown because they contain useful information about the initial rise of the water at that location. The hydrographs are shown in APPENDIX A and are labeled as Figure 1a through 27a. The hydrograph recorded at Duck, NC is shown in Figure 1a. The period is from 0000 UTC 17 September to 0000 UTC 19 September. The dominant regular feature is the semi-diurnal tide oscillation. Superimposed on this tide oscillation on 18 September is the storm surge caused by Hurricane Isabel. Storm surge is defined as the observed tide minus the predicted astronomical tide. Thus, to determine the hydrograph of the storm surge, it is necessary to subtract the astronomical tide. This was done by using predicted hourly and maximum and minimum National Ocean Service (NOS) tide values and subtracting them from the actual hydrograph. Figure 1b shows the same hydrograph as Figure 1a. with the NOS-predicted tide curve and the storm surge hydrograph. It is useful to note that the peak storm surge occurred near high astronomical tide.

Using this technique to remove the astronomical tide, the storm surge hydrographs for the remaining 26 stations were determined. Note that the 3 river tide gages that flow into Pamlico Sound in North Carolina, which were supplied to us via the internet from the USGS, have almost no tidal signal. For these locations no adjustments were done. The 27 measured storm surge hydrographs are shown in figures 1b through 27b.

Plotted in figures 1c through 27c are the observed storm surge hydrographs from figures 1b through 27 b and the SLOSH model-generated storm surge hydrographs for the same location based upon Hurricane Isabel input parameters as shown in Figure 3. However, the initial water elevation for these SLOSH model runs were set to zero elevation because we are comparing storm surges only.

COMPARISON OF THE RESULTS IN THE PAMLICO SOUND, NC BASIN:

1. At Duck the peak storm surge value generated by SLOSH as well as the time of arrival of the

surge compare very well with the observed.

2. At the Hatteras Fishing Pier the tide gage was destroyed before the peak storm surge arrived. The SLOSH hydrograph starts off lower than the observed but does capture the rate of rise of the water. Because of this the SLOSH hydrograph appears to be running about 2 hours late. However, it is evident from the observed storm surge hydrograph that the water surface was elevated about a foot at about 2100 UTC on the 17^{th} of September which was not captured by the SLOSH model. If the SLOSH hydrograph is elevated by this amount the phase problem disappears and the comparison improves dramatically. This adjustment is shown in Figure 1 in APPENDIX B. Figure 2 in APPENDIX B shows a computation of a hypothetical tide gage hydrograph for the Hatteras Fishing Pier based upon the addition of the SLOSH adjustment in Figure 1 and the predicted astronomical tide. The resulting hypothetical storm tide maximum at this location is 7.7 feet above mean sea level or 8.8 feet above NGVD29.

3. The Oregon Inlet Marina is located inside of Pamlico Sound and just north of the inlet. As can be seen, the tidal signal is relatively small at this location compared to the Atlantic side. As Isabel approached landfall, the east and southeast winds on the right side of the center drove the water away from the shoreline inside the sound (note: while at the same time piling it up on the Atlantic side as seen in the Duck and the Hatteras Fishing Pier figures). This is seen in the observed tide gage as negative storm surge. As the hurricane continued inland the wind turned toward the south, then southwest and finally west and drove the water in Pamlico Sound up against the east side of the Sound causing a rise in the observed tide gage. The SLOSH hydrograph shows that the model produces a peak surge comparable to the observed but is about 6 hours early and creates a negative surge of about minus two feet which was not observed. The results suggest that the radial extent of the SLOSH model wind field used to drive the water on the southern side of the hurricane (i.e. often referred to the back side of the hurricane) is not large enough and in this case would need to be expanded. This would force the SLOSH model peak closer to the observed.

4. The river gages at Pollockville, Swift Creek and Washington, NC all begin at elevations well above zero, which reflects the fact that they are slightly “up river”. In these three cases, the SLOSH model hydrograph at each location was moved up to have the same initial starting elevation as the river hydrograph. Comparisons at Pollockville and Swift Creek are very reasonable. At Washington, NC located on the Pamlico river the SLOSH model calculated a peak surge that was about a foot too high and about 4 hours late.

COMPARISON OF THE RESULTS IN THE CHESAPEAKE BAY BASIN:

1. At Wachapreague the SLOSH model is a little slow in reaching the maximum storm surge but is near the observed maximum value.

2. At Kiptopeke the phasing is very good but the SLOSH model is high by about 1.7 feet.

3. At the Chesapeake Bay Bridge Tunnel the comparison is very good.

4. At Sewells Point the SLOSH is higher than observed and just a bit late.

5. At Money Point the SLOSH maximum is lower than observed but they occur near the same time.

6. The Richmond Locks are located on the James River near Richmond, Virginia. This is also about 95 river miles from Sewells Point. At this location the highest storm surge of 10.8 feet was observed and can be compared to the next two highest values of 8.1 feet and 8.2 feet at Washington, DC and Chesapeake City, MD respectively. As Isabel moved inland into North Carolina and Southern Virginia the wind field on the right hand side of the hurricane drove water into southern Chesapeake Bay and up the rivers that drain into the bay. The James River is oriented roughly in a west-northwest to east-southeast direction. At some time during the passage of the hurricane Isabel's winds were blowing parallel to the orientation of the river, thus creating optimal wind stress forces on the river's water surface and driving the water up river. Since the river gets narrower as one approaches Richmond the water began to funnel and produced the storm surge as seen in the figure. Later, as the storm surge decreased, freshwater flooding began and produced the higher of the two maxima about two days later. It is interesting to note that the tidal signal is totally removed by the force of the fresh water flooding.

The SLOSH model grid for the Chesapeake Bay basin ends about 12 miles down river from the Richmond Locks. Thus, no grid cell was available to do a direct comparison. Instead, the last grid cell representing the James River at the boundary of the grid was used for the comparison. The phasing of the SLOSH model seems to be good but, as somewhat expected, the amplitude is about four feet too low. If the SLOSH grid extended to Richmond one would expect the SLOSH hydrograph amplitude to be higher.

7. At Gloucester Point, Windmill Point, Lewissetta and Colonial Beach the initial rise of the water in the SLOSH model with the observed is very reasonable.

8. At Washington, DC the hydrographs look very similar but the SLOSH lags behind the observed by about 4 hours.

9. At Annapolis, Baltimore and Tolchester Beach the comparisons are very good.

10. At Chesapeake City the SLOSH peak storm surge is a little low and lags behind the observed by about six hours.

COMPARISON OF THE RESULTS IN DELAWARE BAY:

1. At Lewes the peaks are comparable but the SLOSH is about one hour late.

2. At Ship John Shoal and Reedy Point the SLOSH model is 1.5 and 2.4 feet too high respectively and lags behind the observed by about 5 to 6 hours.

3. At Philadelphia the SLOSH peak is a little low and about 8 hours late.

5.5 Summary of the Comparisons

Table 1 gives a summary of the comparisons of observed storm surge height and time of occurrence and the SLOSH calculated storm surge and time of occurrence. The last column is the gage time minus the SLOSH time to determine the lag at a particular location. Analysis of the time lags suggested a bias in the river data. A second table was created stratifying the data into 3 groups. Open coastal gages, including the Atlantic shoreline and the bay, the river gages, and gages that do not fit either category. Last but not least, a scatter diagram, using the data in table 1, of the observed storm surge and SLOSH calculated storm surge is shown in figure 11. The results of figure 11 and table 2 are discussed in the conclusions.

6.0 CONCLUSIONS

Comparison of the SLOSH model winds to two over-the-water observing sites, Duck, NC and the Chesapeake Bay Bridge Tunnel, showed reasonable results, with the SLOSH model maximum wind about 10 mph higher than the observed. However, with these winds the SLOSH model produced very reasonable storm surge hydrographs when compared to the observed. The maximum winds observed at the northern end of Chesapeake Bay were much larger than standard wind decay models calculated. When the SLOSH model wind field was adjusted to produce the observed wind field (i.e. with a 10 mph high bias), the storm surge results improved dramatically in the northern end of the Chesapeake Bay.

For hurricane Isabel (2003), comparison of 397 observed high water marks (i.e. wave contaminated marks removed) in North Carolina, Virginia and Maryland yielded typical storm surge model error characteristics, with a majority of the SLOSH/Tide calculated values within plus or minus 20 percent of the observed. Also, the differences between the observed high water marks and the SLOSH/Tide generated values showed that 80% of the values fell between plus 1.5 to minus 1.5 feet and 96% are within plus 2.5 to minus 2.5 feet.

Figure 11 shows the comparison of the maximum observed storm surge to the SLOSH model calculated storm surge maximum for 21 tide gages. Over all the comparison is reasonable except at two locations in the Delaware Bay - Reedy Point and Ship John Shoal and two locations in the Chesapeake Bay - Kiptopeke and Money Point. Comparison of the time of observed maximum storm surge to the time of the SLOSH generated maximum in Table 1 showed significant differences in errors in time between gages near the coast and gages in the rivers. From Table 1 the locations of the tide gage locations were broken into three groups; coastal or near coastal gages, river gages and miscellaneous (i.e. does not fit either coastal or river). The results are presented in table 2 and show very good phase comparisons for the coastal locations but a large negative lag in the rivers. In other words, the storm surge in the SLOSH model is arriving many hours late when compared to the observed, even though the maximum heights of the storm surge are very reasonable when compared to each other at these locations.

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Hovis, Jerry, W. Popovich, C. Zervas, J. Hubbard, H. H. Shih, P. Stone, 2004: Effects of hurricane Isabel on water levels data report, NOAA Technical Report NOS CO-OPS 40, Washington, D.C., 120 pp.

Table 1. Comparison of Observed and SLOSH Storm Surge maximums and time of occurrence for 22 locations for hurricane Isabel (2003). * Comparison not at same location. 5 locations NA means incomplete record. Gage time differences in last column.

Station Name	Gage MAX (ft)	Time of Gage MAX (UTC)	SLOSH MAX (ft)	Time of SLOSH MAX (UTC)	Gage Time minus SLOSH Time (hrs)
Annapolis, US Naval Academy, MD	6.3	9/19/04 12:00	6.4	9/19/04 12:00	0
Baltimore, MD	7.3	9/19/04 12:00	7.2	9/19/04 12:00	0
Cambridge, Choptank River, MD	5.2	9/19/04 10:00	4.6	9/19/04 15:00	-5
Cape Hatteras Fishing Pier	NA	NA	5	9/18/04 16:00	NA
Chesapeake Bay Bridge Tunnel, VA	4.8	9/18/04 20:00	4.7	9/18/04 19:00	-1
Chesapeake City, MD	8.2	9/19/04 14:00	6.6	9/19/04 21:00	-6
Colonial Beach, Potomac River, VA	NA	NA	6.9	9/19/04 6:00	NA
Duck USACE FRF, NC	4.7	9/18/04 16:00	4.6	9/18/04 17:00	-1
Gloucester Point, York River, VA	NA	NA	7.5	9/18/04 23:00	NA
Kiptopeke, Chesapeake Bay, VA	3.9	9/18/04 20:00	5.4	9/18/04 21:00	-1
Lewes, DE	3.1	9/19/04 1:00	3.4	9/19/04 2:00	-2
Lewisetta, Potomac River, VA	4.0	9/19/04 1:00	4.9	9/19/04 3:00	0
Money Point, Elizabeth River, VA	5.7	9/18/04 22:00	4.4	9/18/04 22:00	0
Oregon Inlet Marina, NC	4.7	9/19/04 3:00	4.3	9/18/04 22:00	5
Philadelphia, PA	5.4	9/19/04 8:00	4.7	9/19/04 16:00	-8
Pollockville, NC	5.6	9/18/04 23:00	6	9/18/04 21:00	2
Reedy Point, DE	5.0	9/19/04 5:00	7.4	9/19/04 10:00	-5
Richmond Locks, VA	10.8	9/19/04 5:00	6.8*	9/19/2004 6:00*	-1
Sewells Point, VA	5.6	9/18/04 21:00	6.8	9/18/04 22:00	-1
Ship John Shoal, NJ	4.7	9/19/04 3:00	6.4	9/19/04 9:00	-5
Solomon Island, MD	NA	NA	5	9/19/04 7:00	NA
Swift Creek, NC	5.0	9/19/04 0:00	5.4	9/19/04 0:00	0
Tolchester Beach, MD	6.9	9/19/04 13:00	6.8	9/19/04 13:00	0
Wachapreague, VA	5.0	9/18/04 21:00	5	9/18/04 23:00	-2
Washington, NC	6.2	9/19/04 0:00	7	9/19/04 3:00	-3
Washington, DC	8.1	9/19/04 10:00	8	9/19/04 14:00	-4
Windmill Point, VA	NA	NA	7.6	9/18/04 23:00	NA

Table 2. The range of the Coastal areas are 0 to -2 hours and the river areas are ranging +2 to -8.

Station Name	Coast al	River s	Miscellaneo us
Annapolis, US Naval Academy, MD	0		
Baltimore, MD	0		
Cambridge, Choptank River, MD		-5	
Cape Hatteras Fishing Pier			NA
Chesapeake Bay Bridge Tunnel, VA	-1		
Chesapeake City, MD		-6	
Colonial Beach, Potomac River, VA			NA
Duck USACE FRF, NC	-1		
Gloucester Point, York River, VA			NA
Kiptopeke, Chesapeake Bay, VA	-1		
Lewes, DE	-2		
Lewisetta, Potomac River, VA	0		
Money Point, Elizabeth River, VA	0		
Oregon Inlet Marina, NC			5
Philadelphia, PA		-8	
Pollockville, NC		2	
Reedy Point, DE		-5	
Richmond Locks, VA		-1	
Sewells Point, VA	-1		
Ship John Shoal, NJ		-5	
Solomon Island, MD			NA
Swift Creek, NC		0	
Tolchester Beach, MD	0		
Wachapreague, VA	-2		
Washington, NC		-3	
Washington, DC		-4	
Windmill Point, VA			NA

Figure Captions

Figure 1a. Chesapeake Bay SLOSH basin grid.

Figure 1b. Pamilico Sound SLOSH basin grid.

Figure 2. Track of Hurricane Isabel, 6 September to 20 September 2003. Positions are given at every 12 hours at 0000 and 1200 UTC. The date is located at the 1200 UTC position. (See legend).

Figure 3. Track of Hurricane Isabel. Hourly locations are indicated with a hurricane symbol. Legend example: 1500/957/54 – 1500 UTC/ 957 mb central sea level pressure / 54 statute miles radius of maximum winds.

Figure 4a. Surface isobaric analysis at 1800 UTC18 September 2003. Contour interval is 5 mb. Surface wind speed and direction are also included.

Figure 4a. Surface isobaric analysis at 1800 UTC18 September 2003. Contour interval is 5 mb. Surface wind speed and direction are also included.

Figure 4b. Surface isobaric analysis at 0200 UTC19 September 2003. Contour interval is 5 mb. Surface wind speed and direction are also included.

Figure 4c. Surface isobaric analysis at 1000 UTC19 September 2003. Contour interval is 5 mb. Surface wind speed and direction are also included.

Figure 5a. Observed and SLOSH calculated one-minute wind speeds at the Duck, North Carolina Field Research Facility (FRF).

Figure 5b. Observed and SLOSH calculated one-minute wind speeds at the Chesapeake Bay Bridge Tunnel (CBBT), Virginia.

Figure 5c. Observed and SLOSH calculated one-minute wind speeds at the Francis Scott Key Bridge, Baltimore, MD.

Figure 6. Aircraft Reconnaissance wind observations at two minute intervals near the time of Isabel landfall, elevation is 7600 ft msl.

Figure 7a. Location of Observed High Water marks and tide gages in North Carolina.

Figure 7b. Location of Observed High Water marks and tide gages in Virginia, Maryland, Delaware and Pennsylvania.

Figure 8. Observed high water marks vs. SLOSH/Tide Values. With waves.

Figure 9. Observed high water marks vs. SLOSH/Tide Values. With no waves. N = 397

Figure 10. SLOSH/Tide values minus Observed High Water Marks for Hurricane Isabel (2003) with no waves.

Figure 11. Observed Tide Gage Storm Surge Maximum vs. SLOSH Maximum.

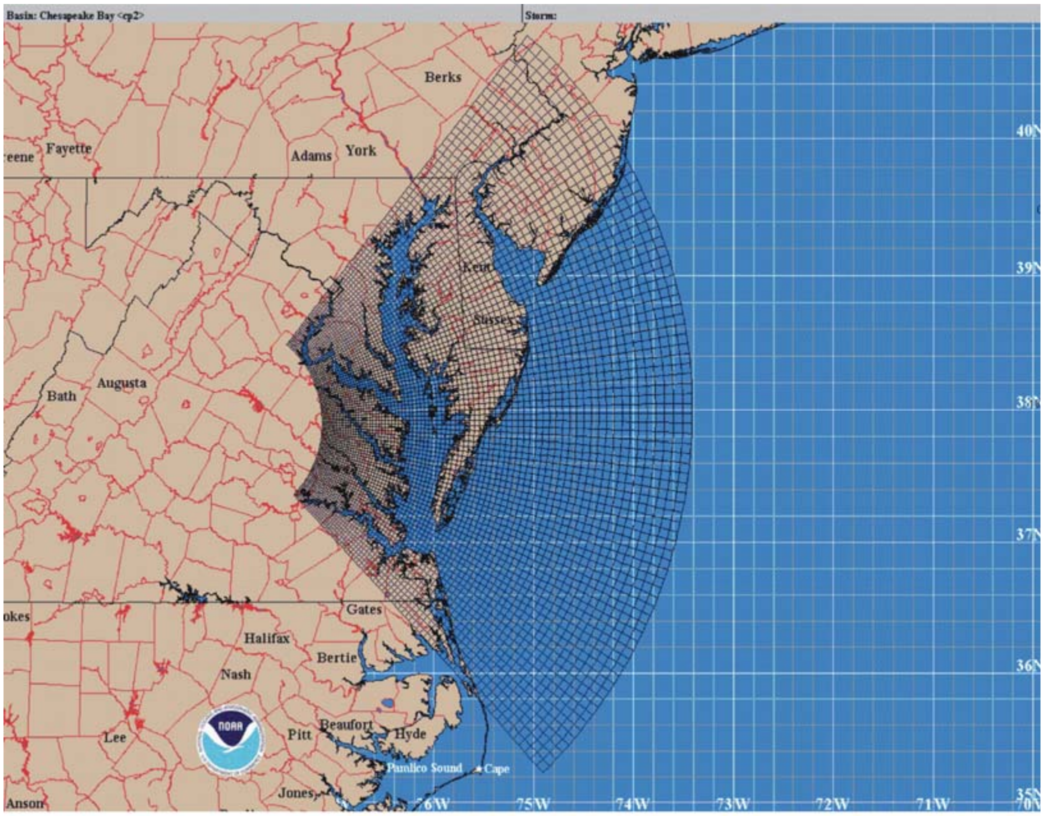


Figure 1a. Chesapeake Bay SLOSH basin grid.

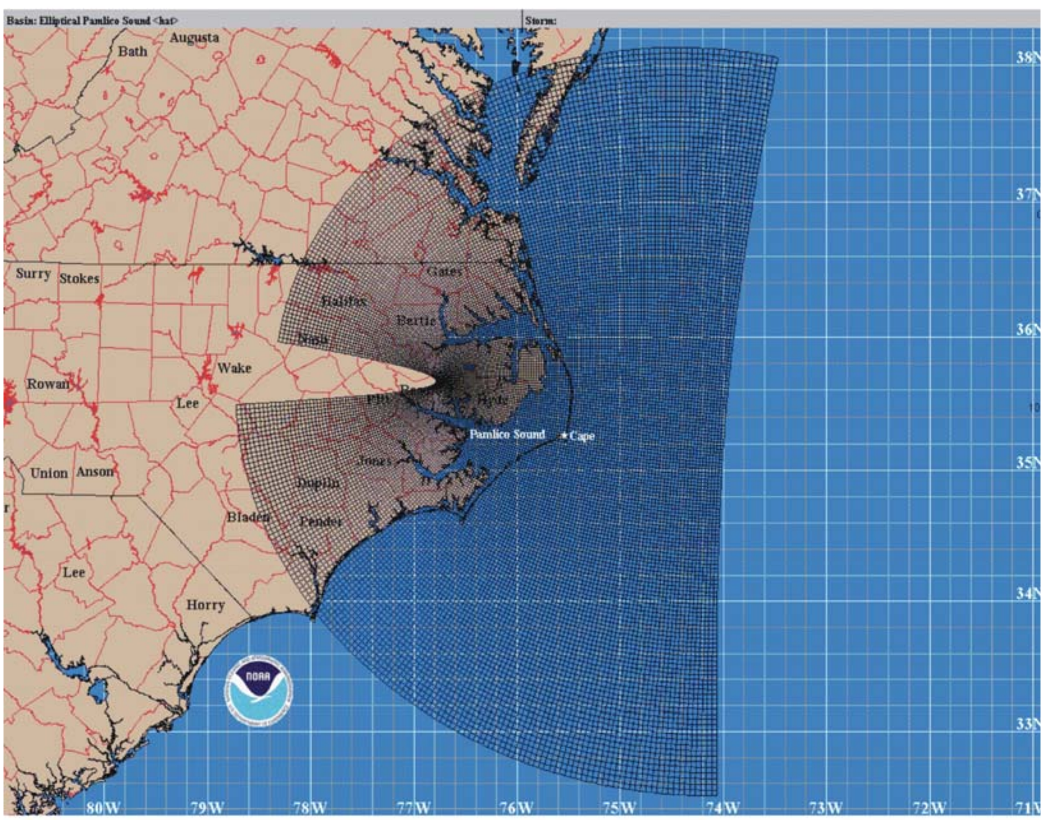


Figure 1b. Pamilico Sound SLOSH basin gri.d.

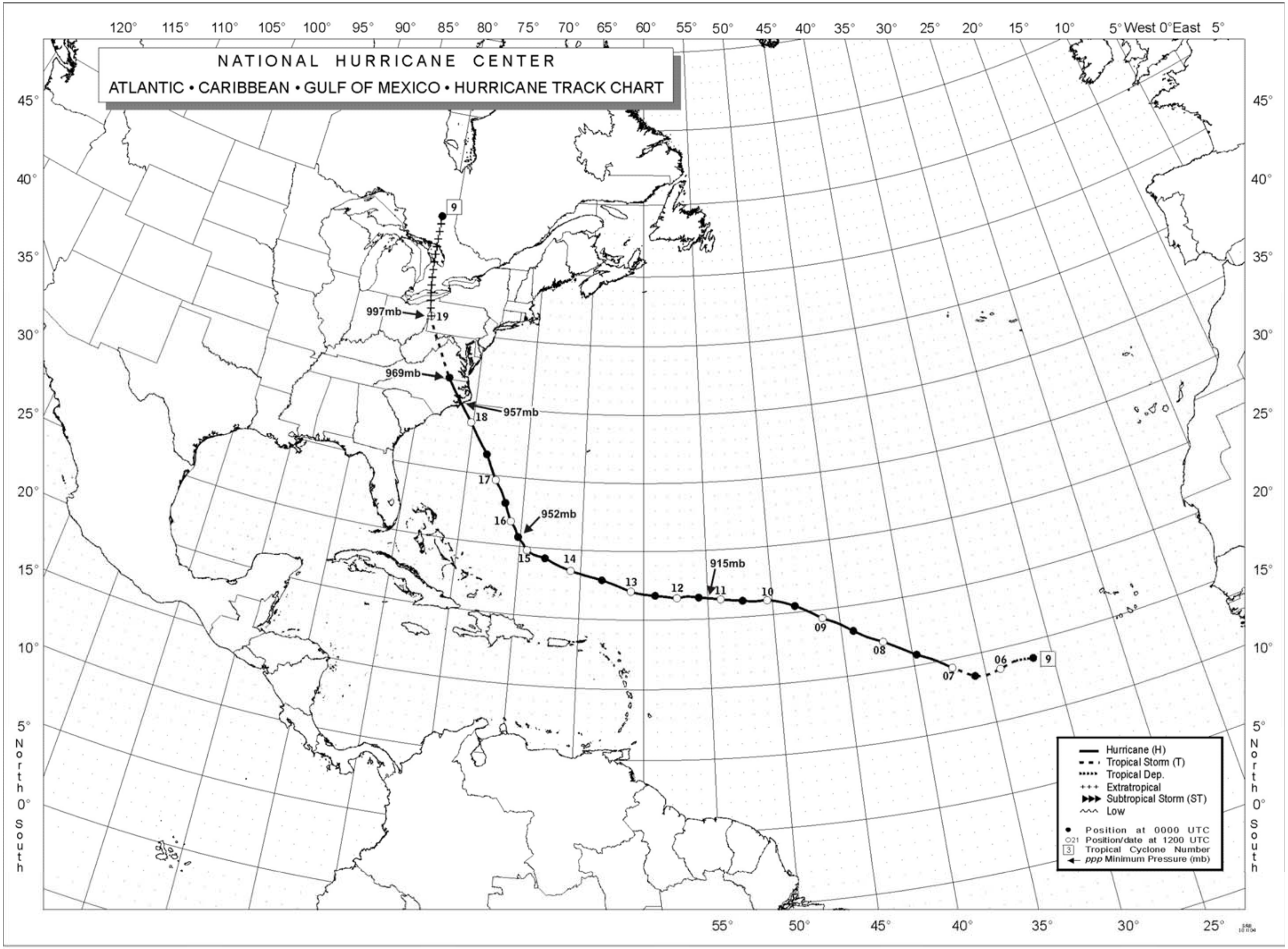


Figure 2. Track of Hurricane Isabel, 6 September to 20 September 2003. Positions are given at every 12 hours at 0000 and 1200 UTC. The date is located at the 1200 UTC position. (See legend).

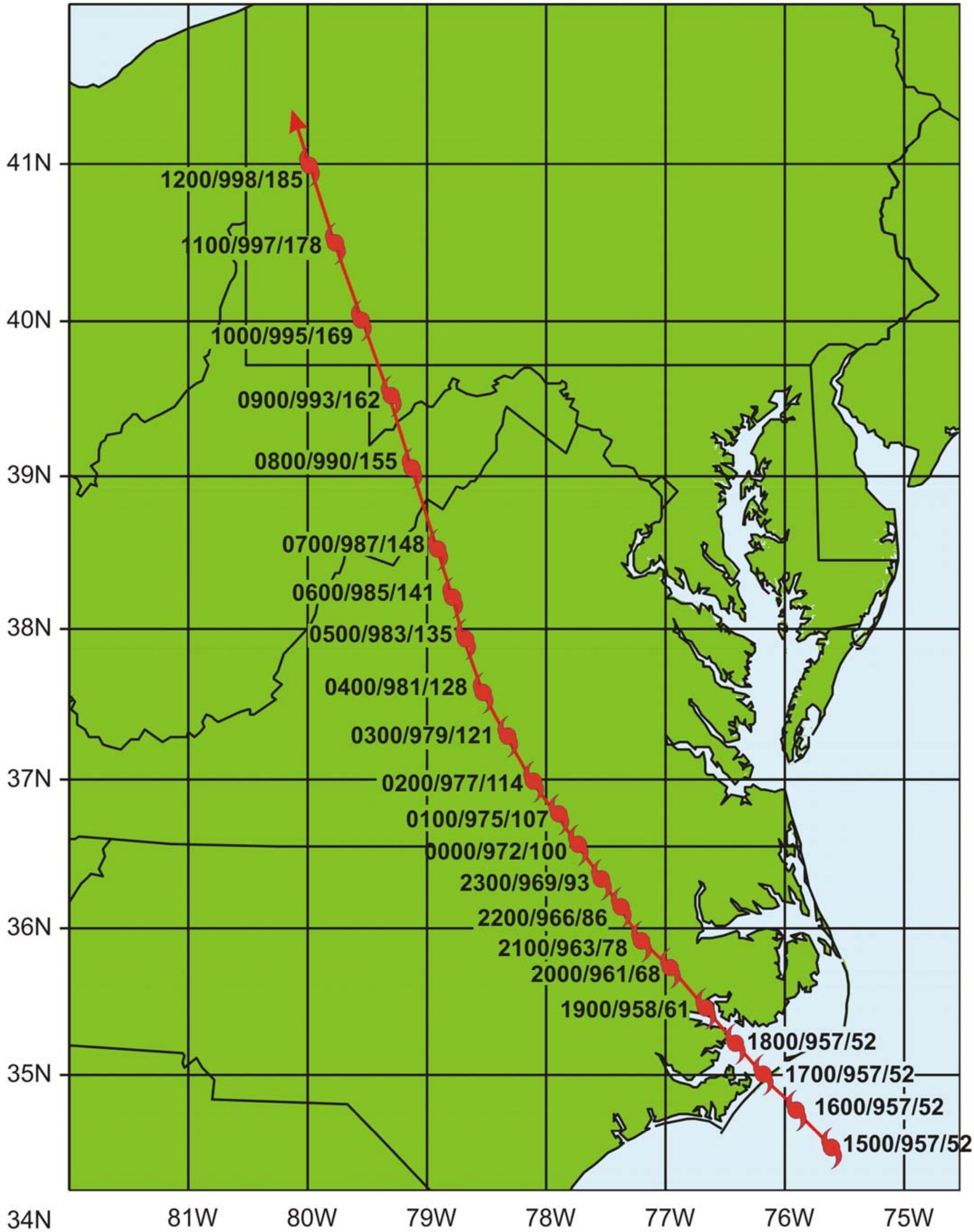


Figure 3. Track of Hurricane Isabel. Hourly locations are indicated with a hurricane symbol. Legend example: 1500/957/54 – 1500 UTC/ 957 mb central sea level pressure / 54 statute miles radius of maximum winds

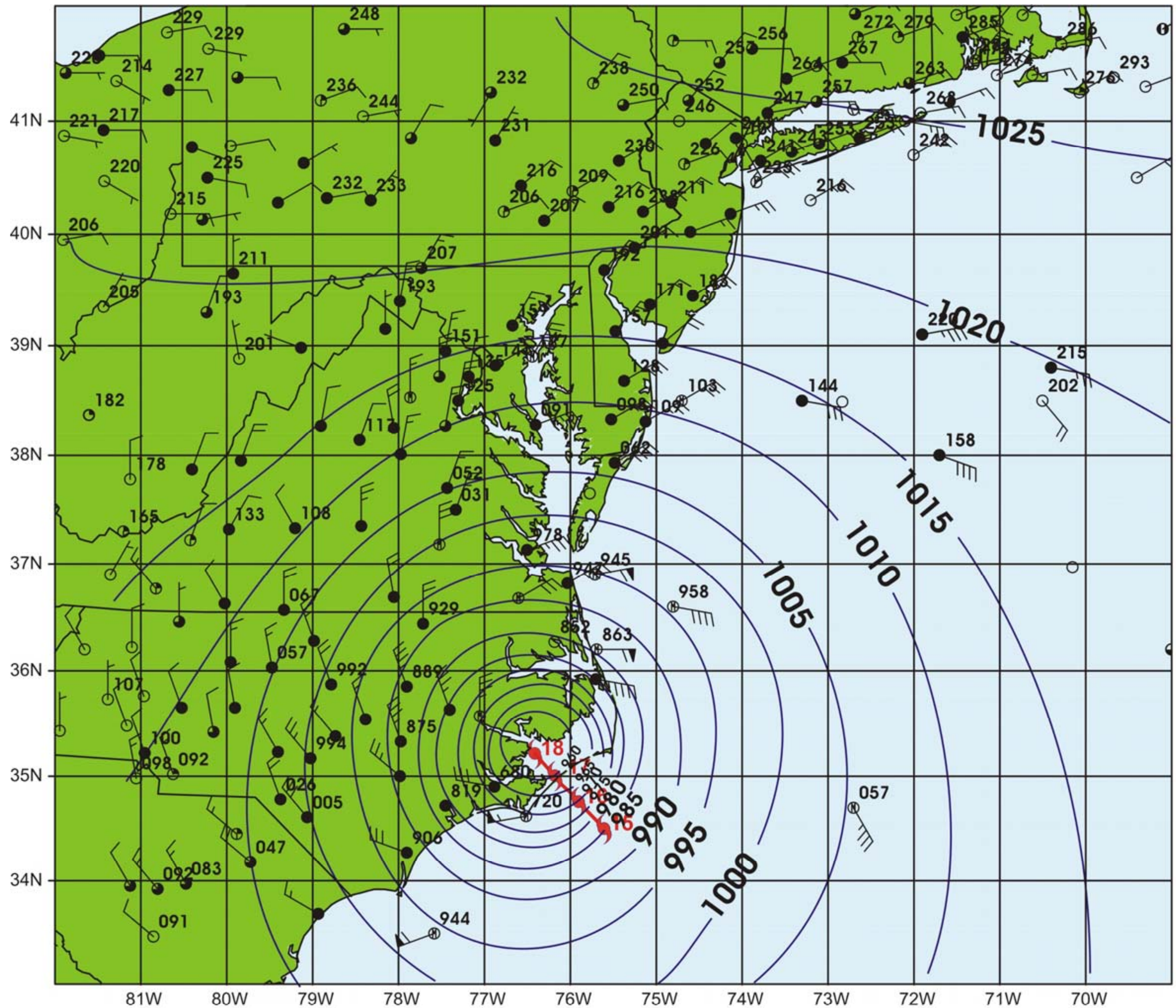


Figure 4a. Surface isobaric analysis at 1800 UTC18 September 2003. Contour interval is 5 mb. Location of observation is indicated by a circle. The pressure value in millibars (mb) is given to the upper right of the circle. Examples: 958 = 995.8 mb; 057 = 1005.7 mb. Wind arrows blow in the direction the wind is going. The barbs indicate speed in knots (kts). A full barb is 10 kts; a one-half barb is 5 kts; a flag is 50 kts. For example, an arrow with 3 full barbs and one-half barb is blowing at 35 kts.

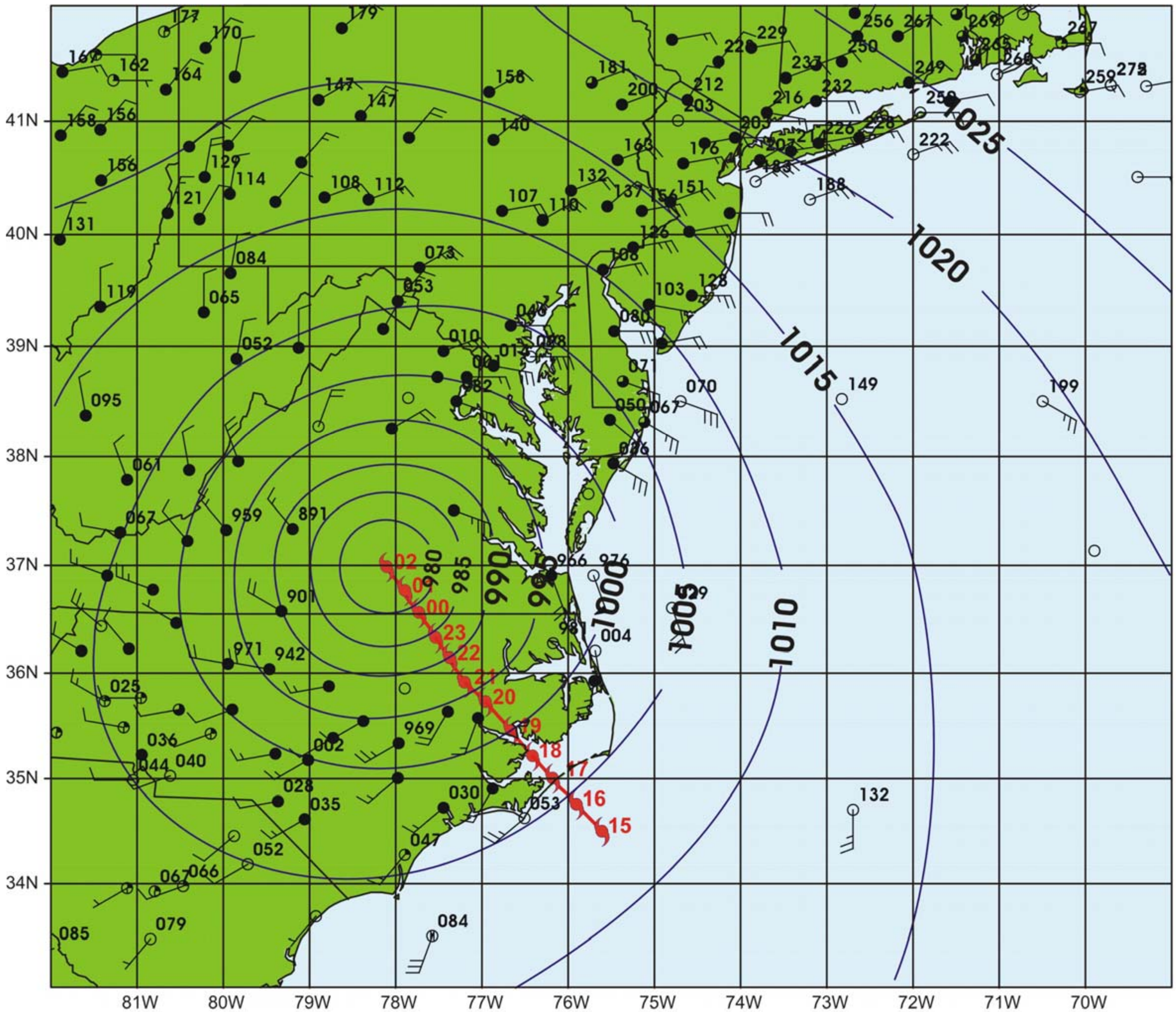


Figure 4b. Surface isobaric analysis at 0200 UTC 19 September 2003. Contour interval is 5 mb. Location of observation is indicated by a circle. The pressure value in millibars (mb) is given to the upper right of the circle. Examples: 958 = 995.8 mb; 057 = 1005.7 mb. Wind arrows blow in the direction the wind is going. The barbs indicate speed in knots (kts). A full barb is 10 kts; a one-half barb is 5 kts; a flag is 50 kts. For example, an arrow with 3 full barbs and one-half barb is blowing at 35 kts.

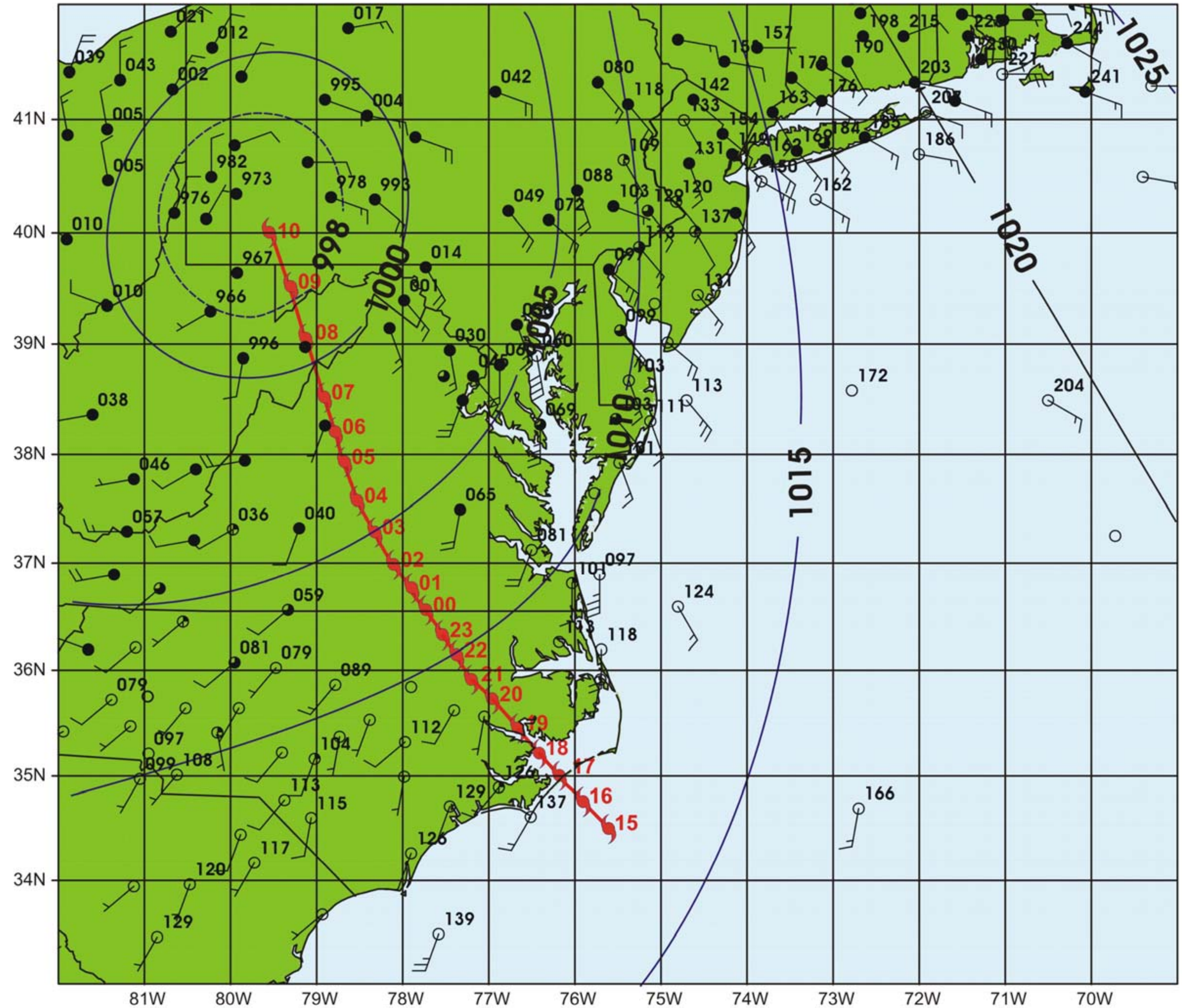


Figure 4c. Surface isobaric analysis at 1000 UTC19 September 2003. Contour interval is 5 mb. Location of observation is indicated by a circle. The pressure value in millibars (mb) is given to the upper right of the circle. Examples: 958 = 995.8 mb; 057 = 1005.7 mb. Wind arrows blow in the direction the wind is going. The barbs indicate speed in knots (kts). A full barb is 10 kts; a one-half barb is 5 kts; a flag is 50 kts. For example, an arrow with 3 full barbs and one-half barb is blowing at 35 kts.

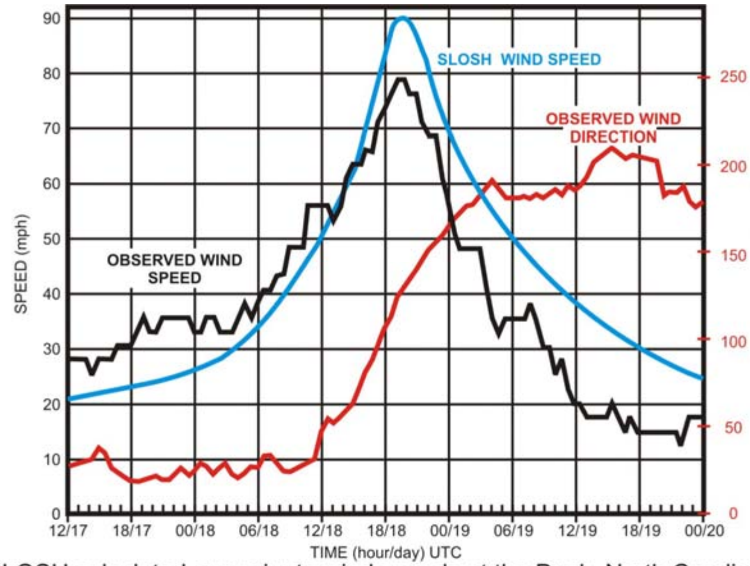


Figure 5a. Observed and SLOSH calculated one-minute wind speeds at the Duck, North Carolina Field Research Facility (FRF).

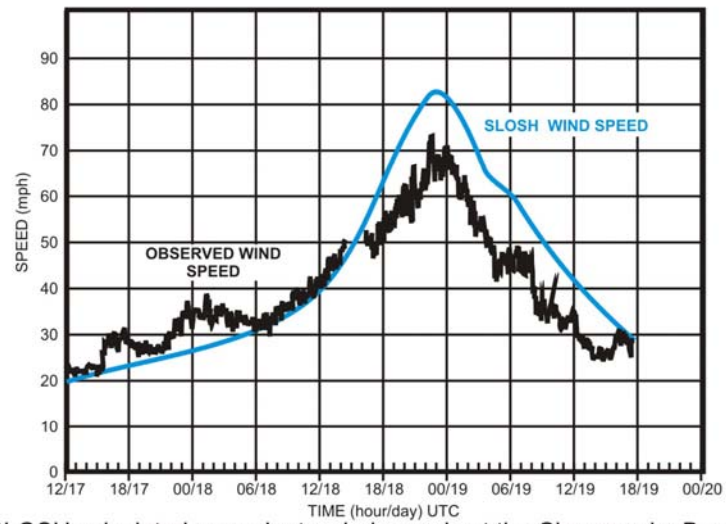


Figure 5b. Observed and SLOSH calculated one-minute wind speeds at the Chesapeake Bay Bridge Tunnel (CBBT), Virginia

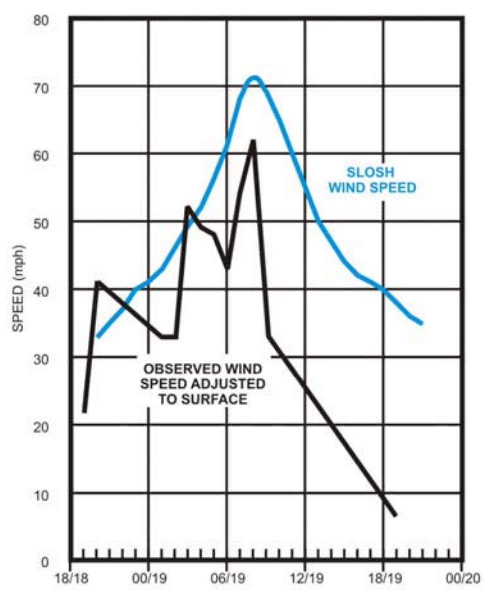


Figure 5c. Observed and SLOSH calculated one-minute wind speeds at the Francis Scott Key Bridge, Baltimore, MD.

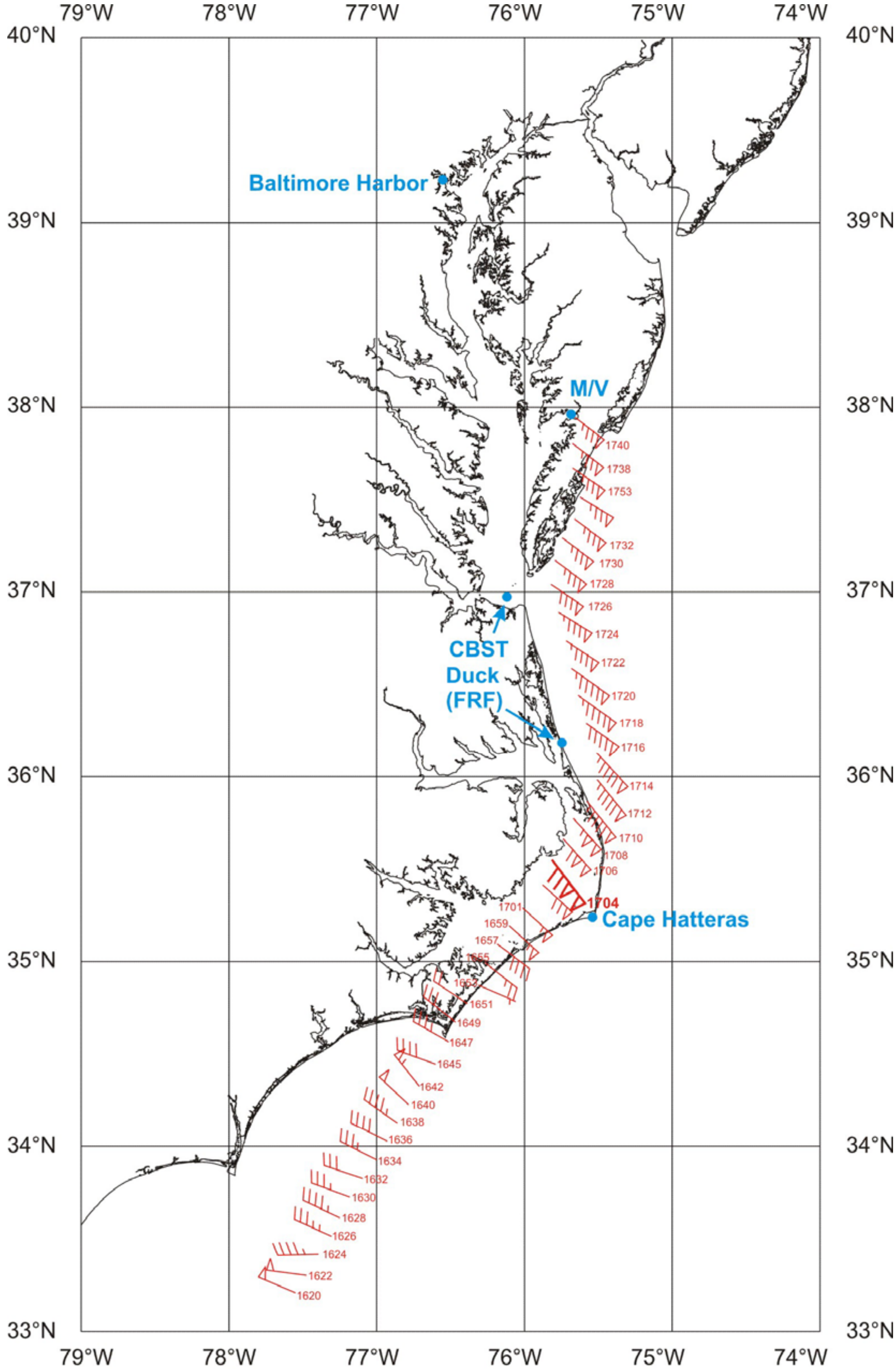


Figure 6. Aircraft Reconnaissance wind observations at two minute intervals near the time of Isabel landfall, elevation is 7600 ft msl.

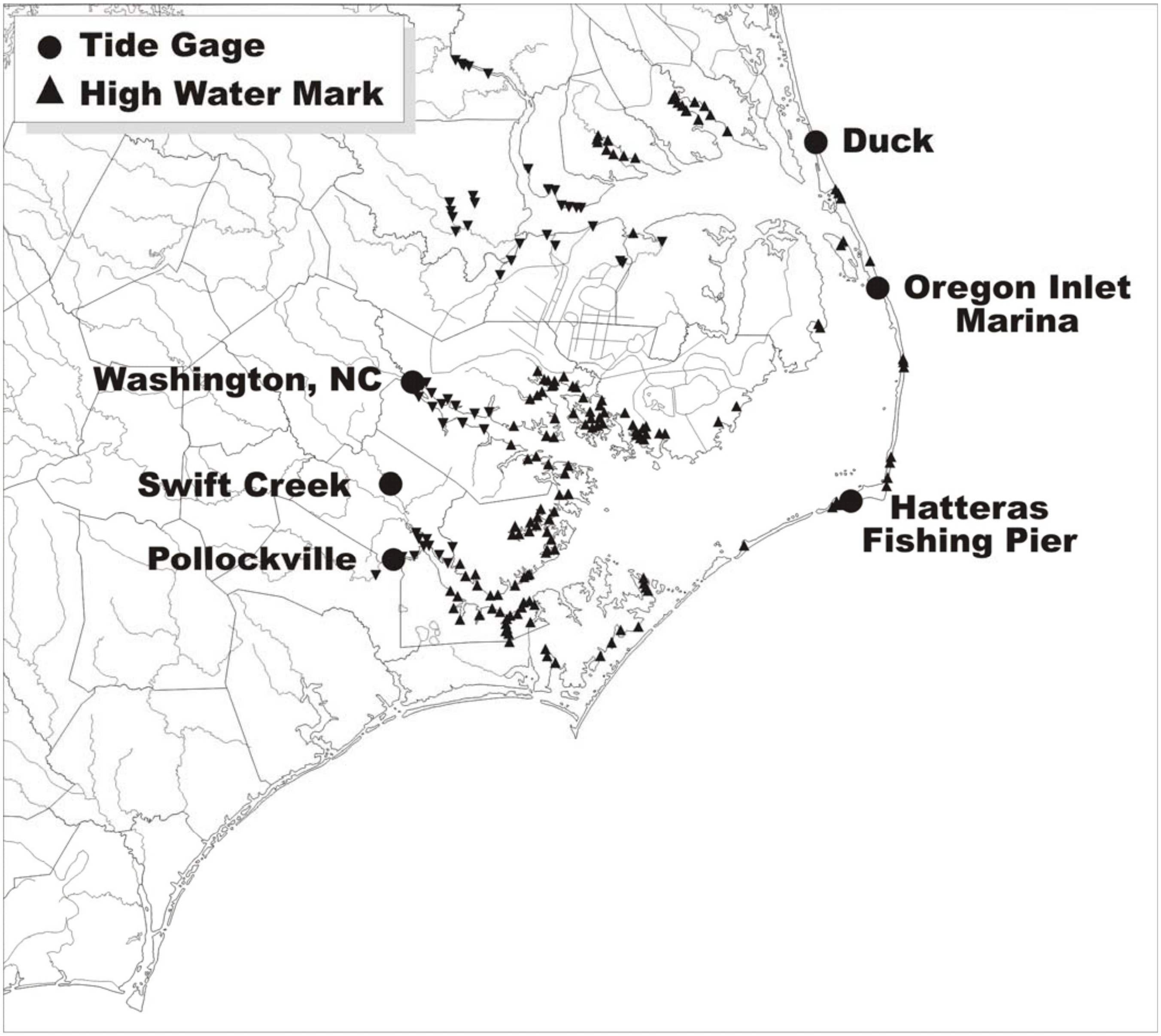


Figure 7a. Location of Observed High Water marks and tide gages in North Carolina.

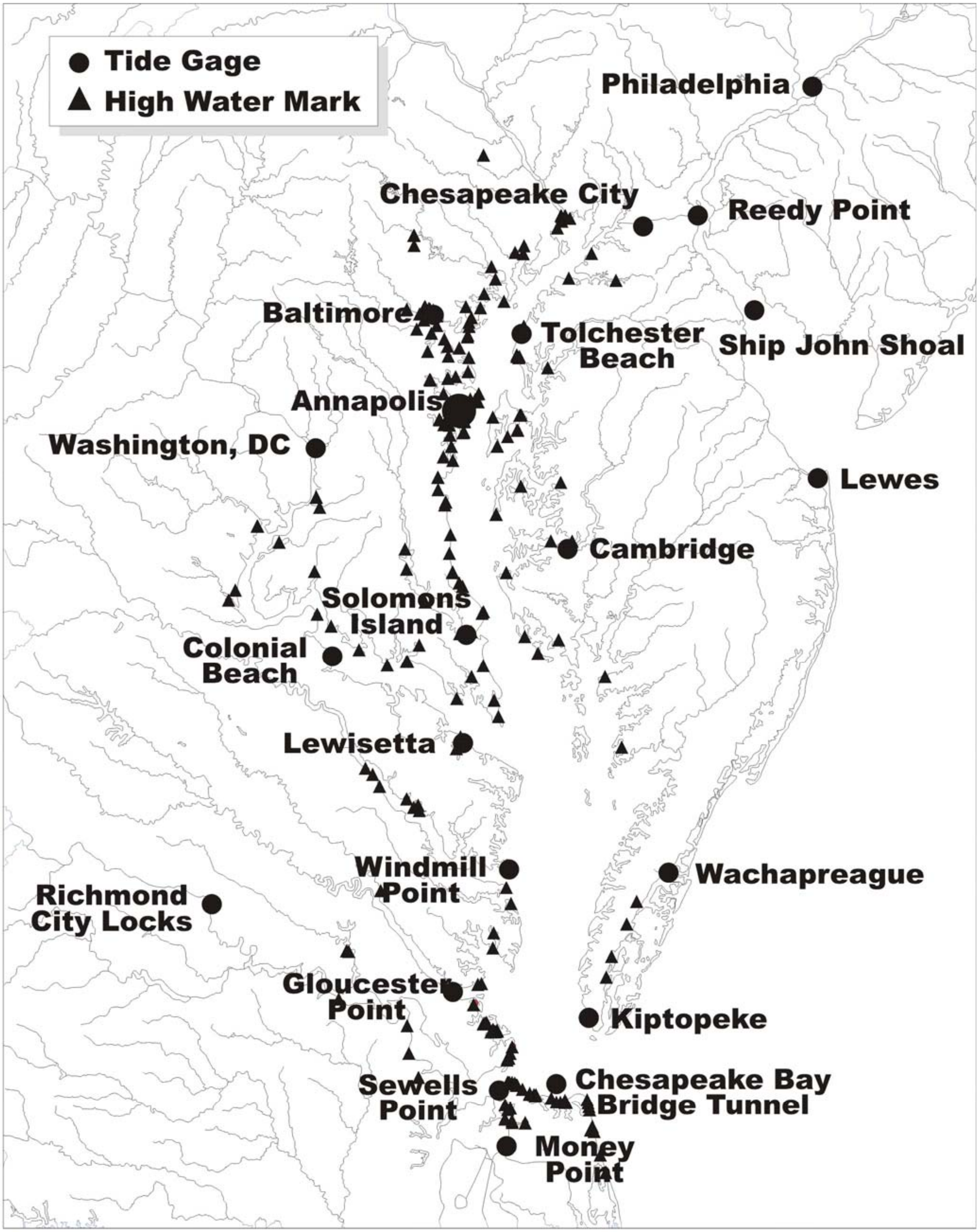


Figure 7b. Location of Observed High Water marks and tide gages in Virginia, Maryland, Delaware and Pennsylvania.

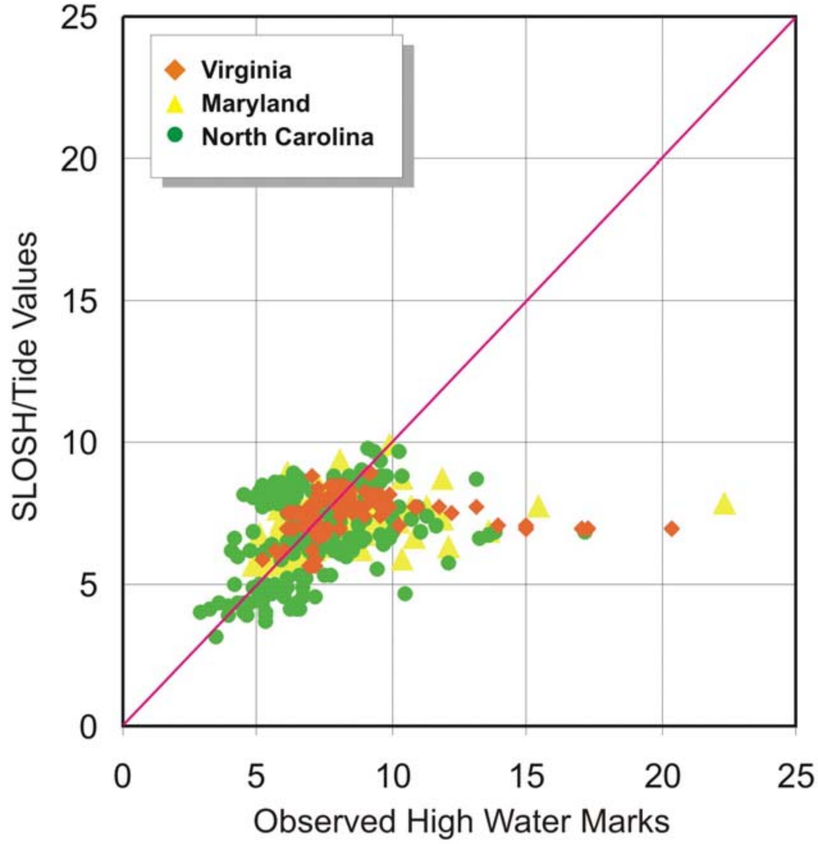


Figure 8. Observed high water marks vs. SLOSH/Tide Values. With waves. N = 454.

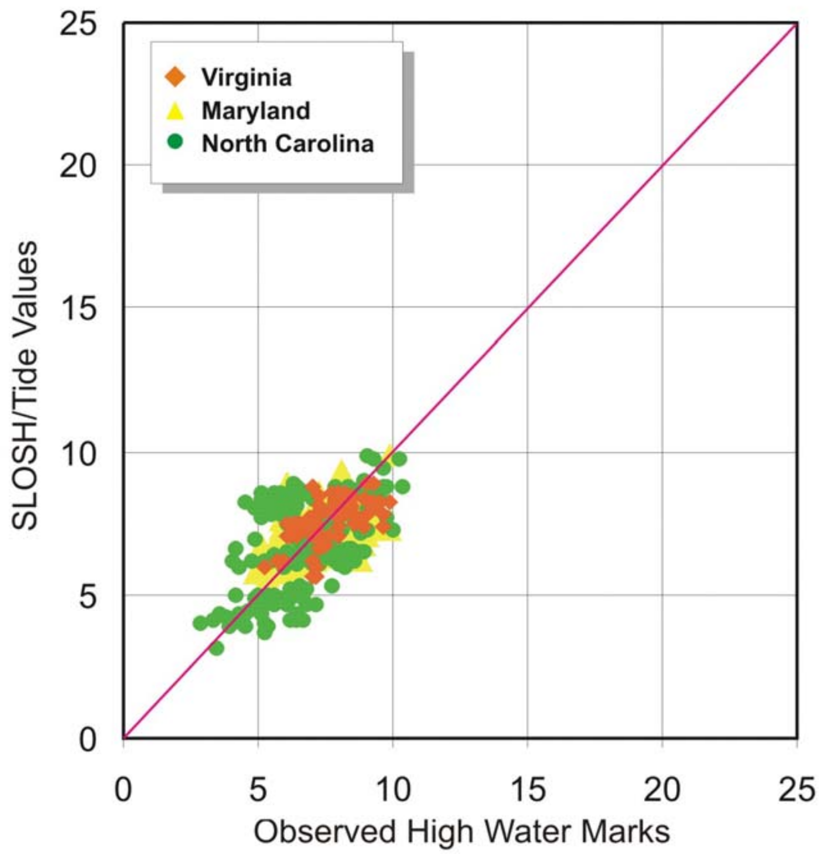


Figure 9. Observed high water marks vs. SLOSH/Tide Values. With no waves. N = 397

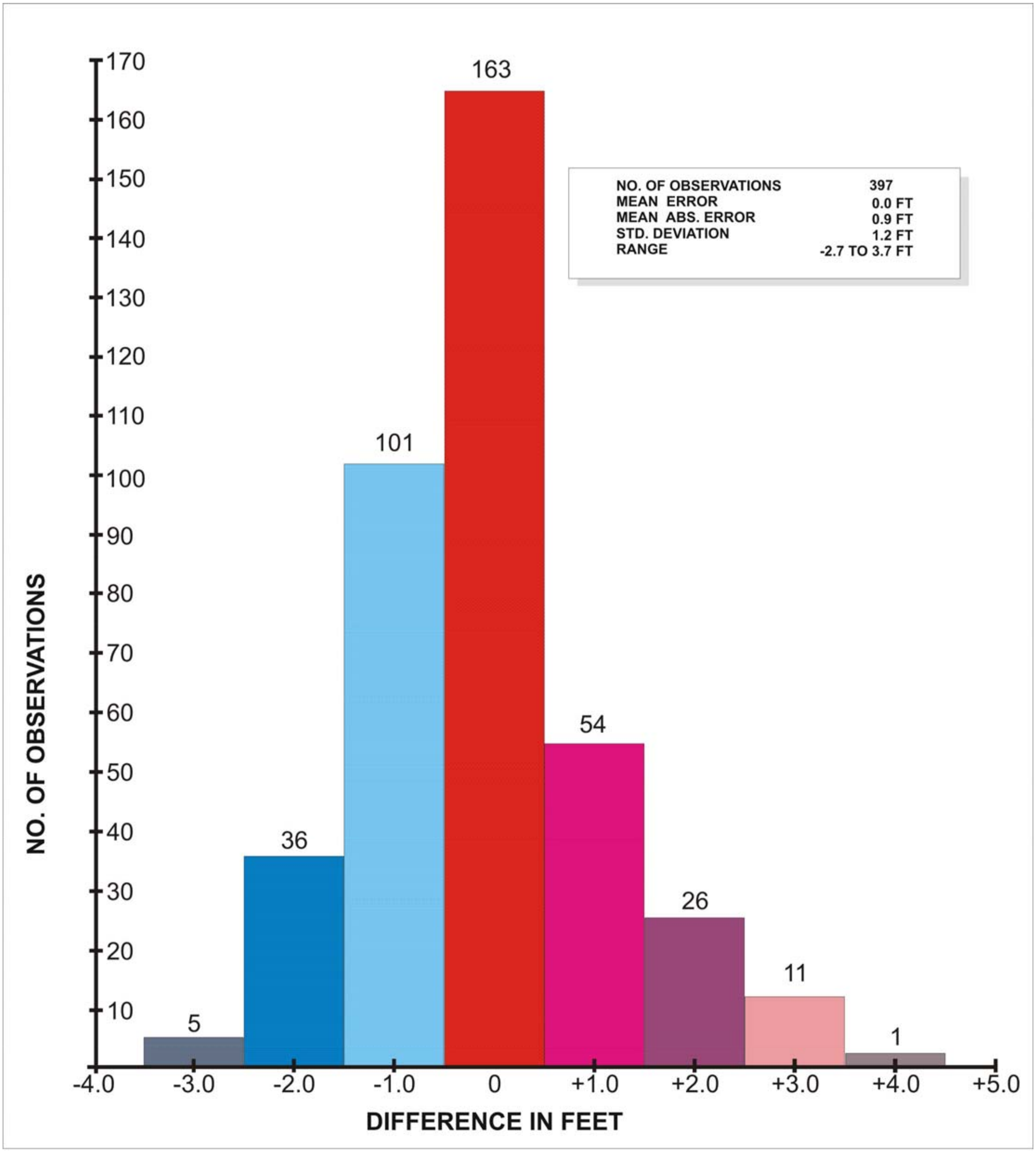


Figure 10. SLOSH/Tide values minus Observed High Water Marks for Hurricane Isabel (2003) (with no waves).

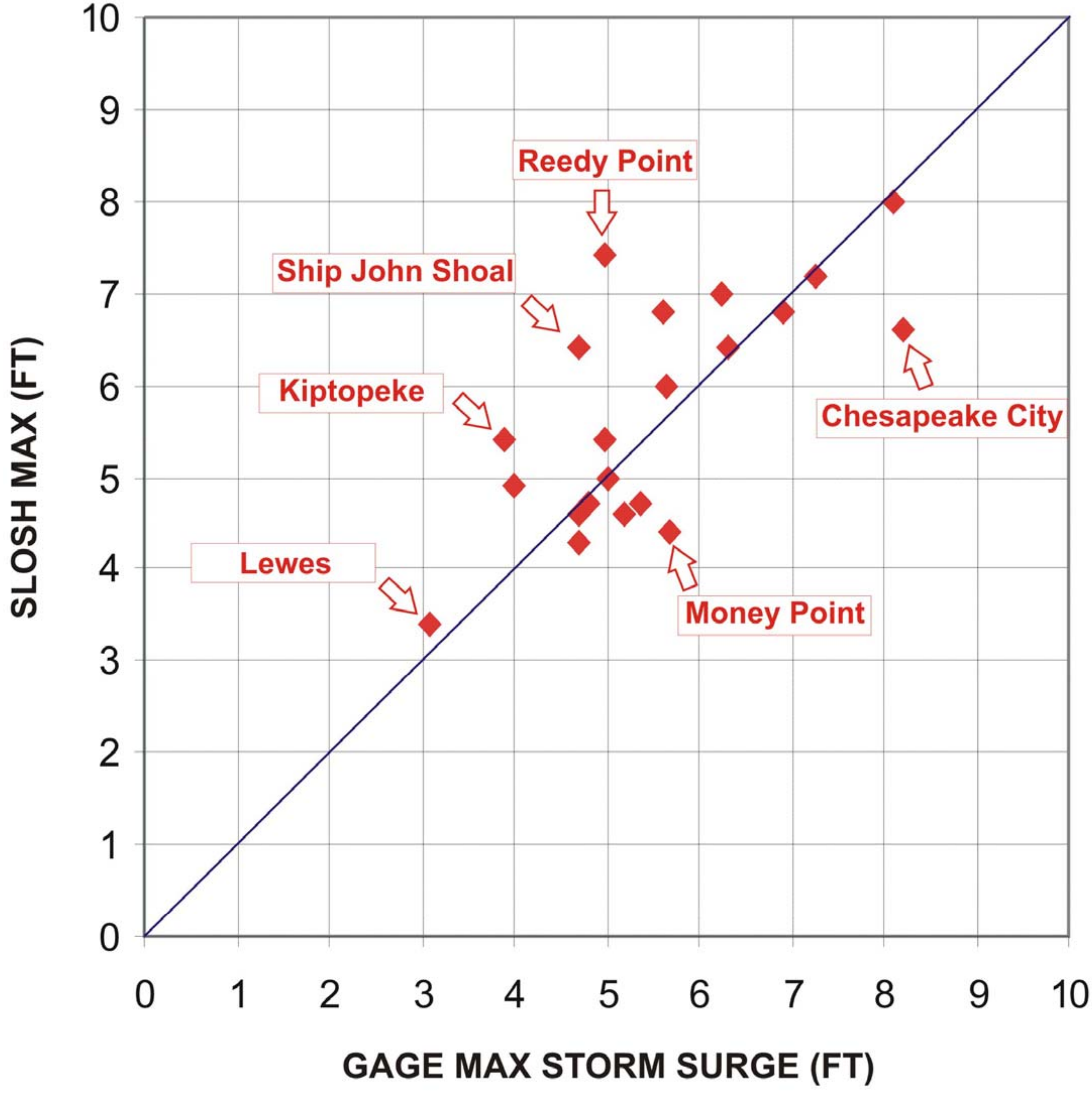
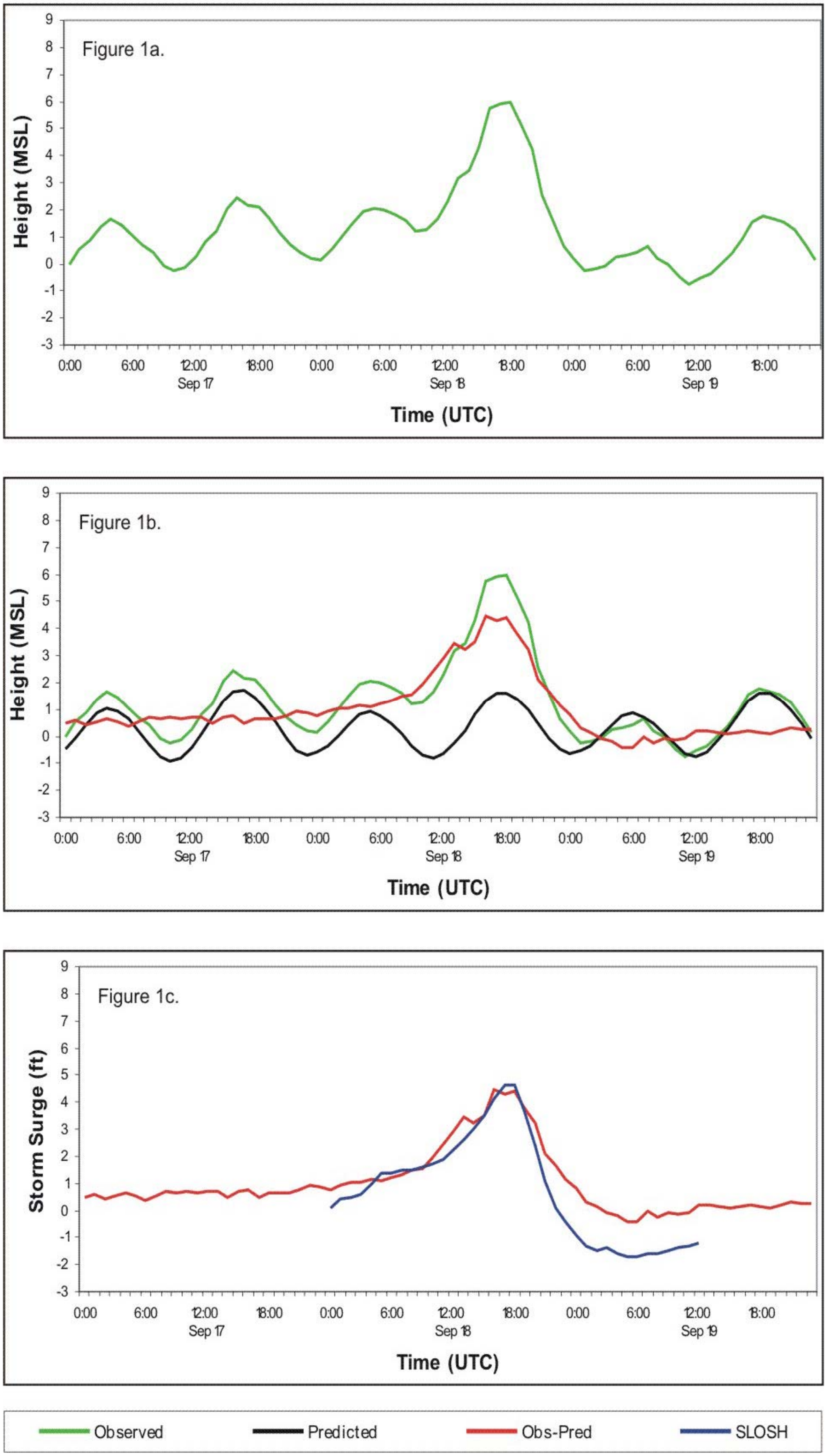


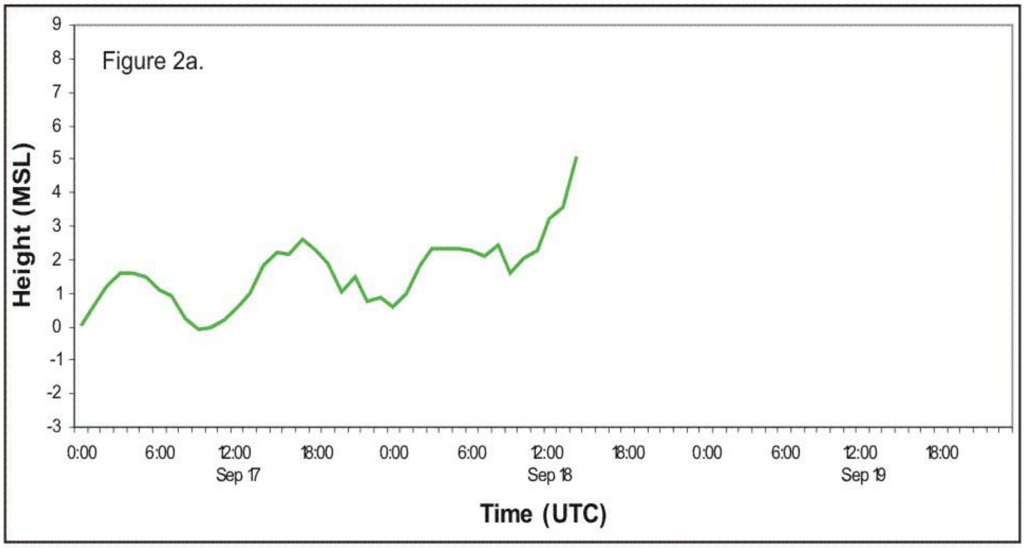
Figure 11. Observed Tide Gage Storm Surge Maximum vs. SLOSH Maximum

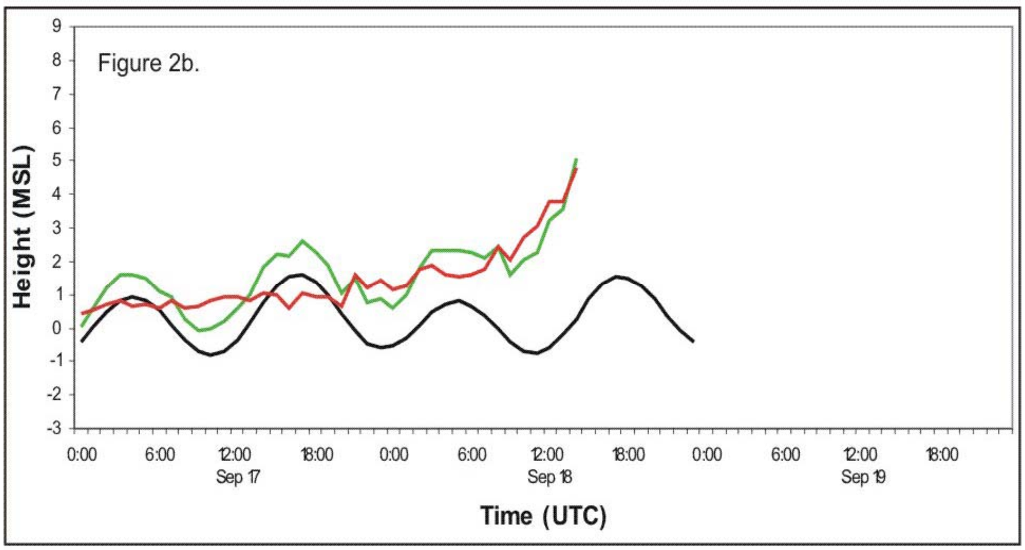
APPENDIX A

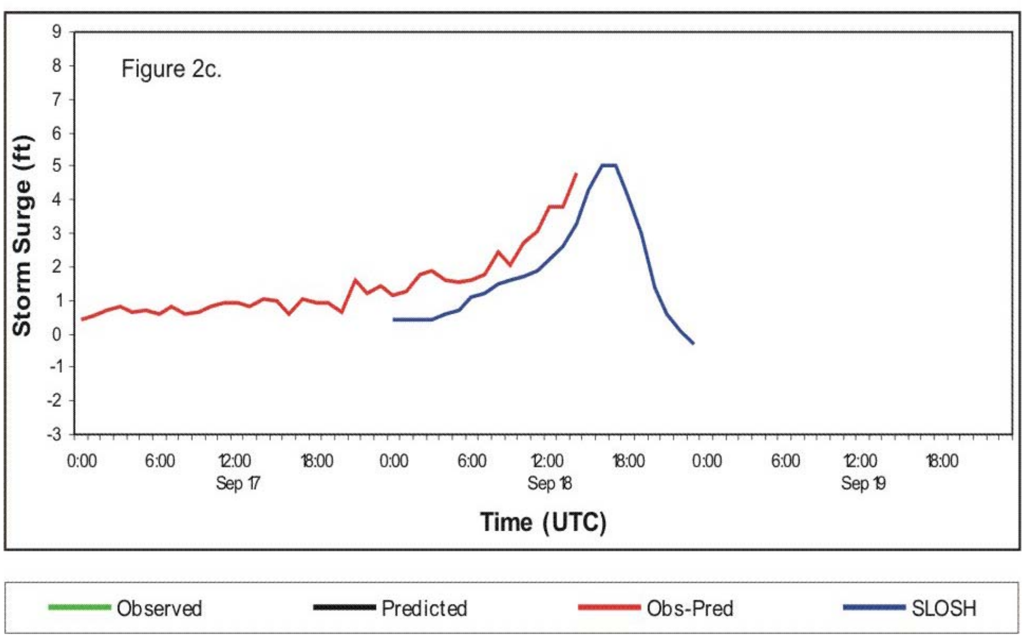
Duck USACE FRF, NC



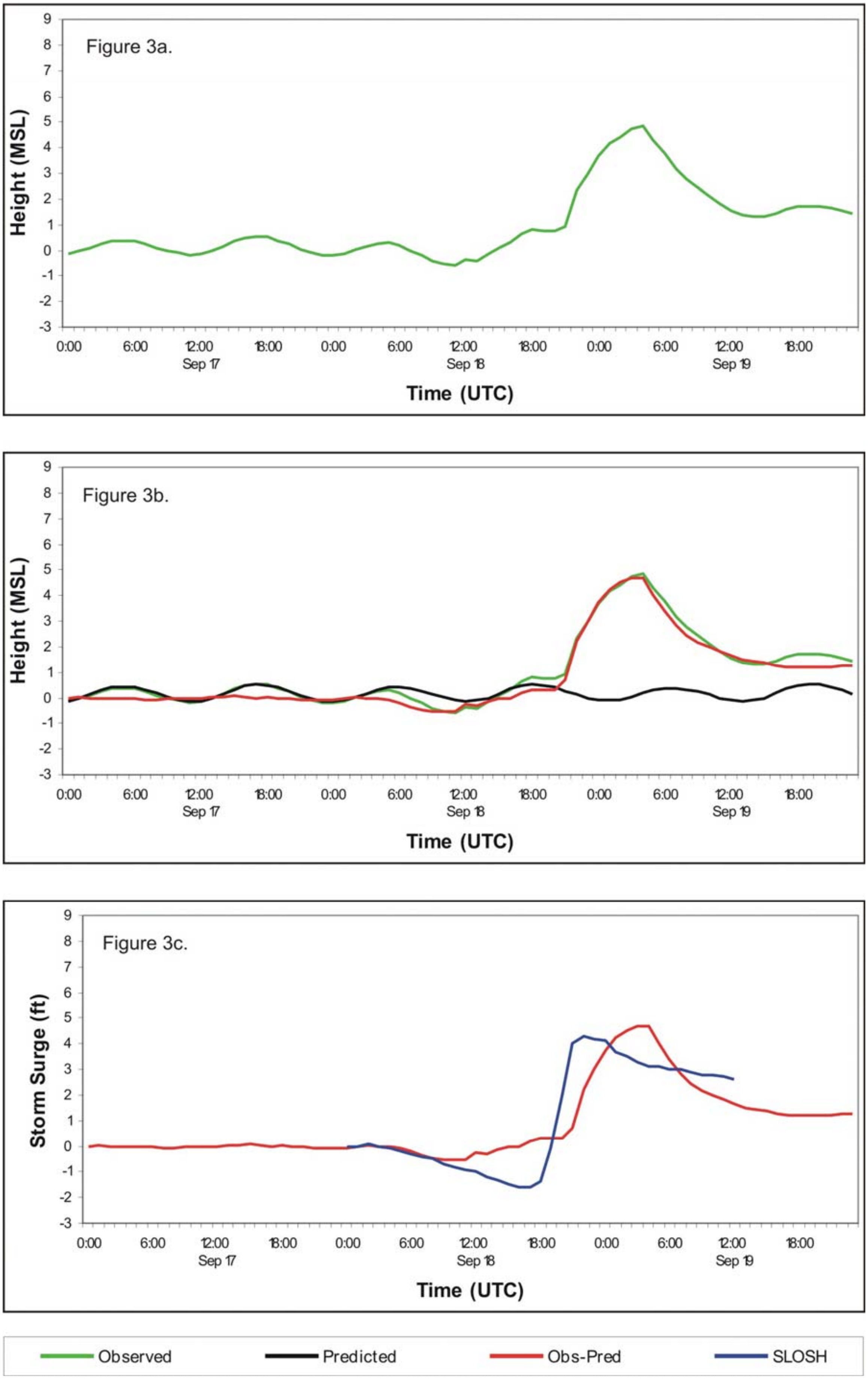
Cape Hatteras Fishing Pier



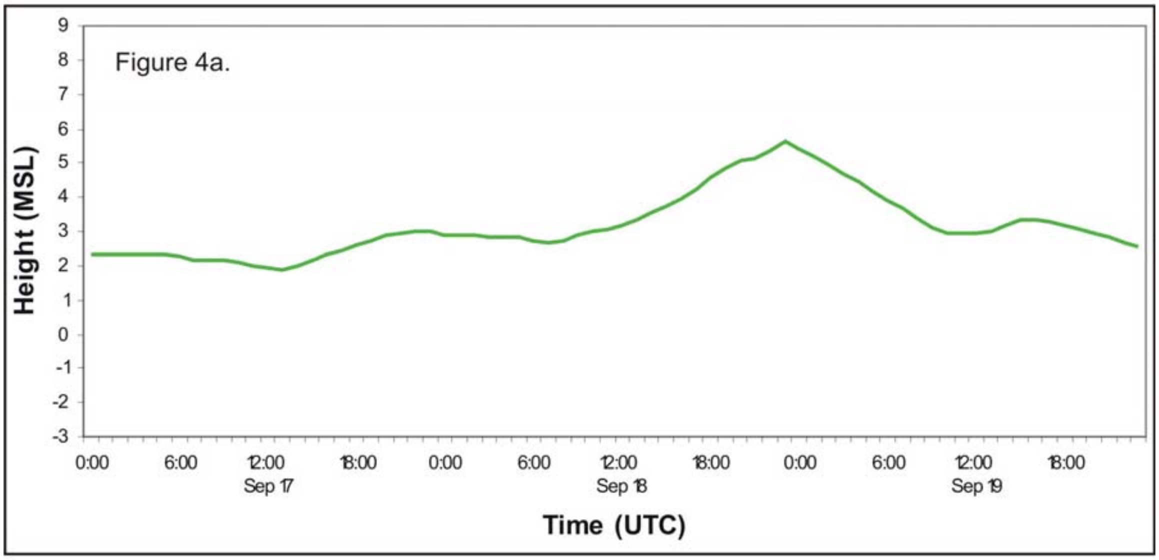


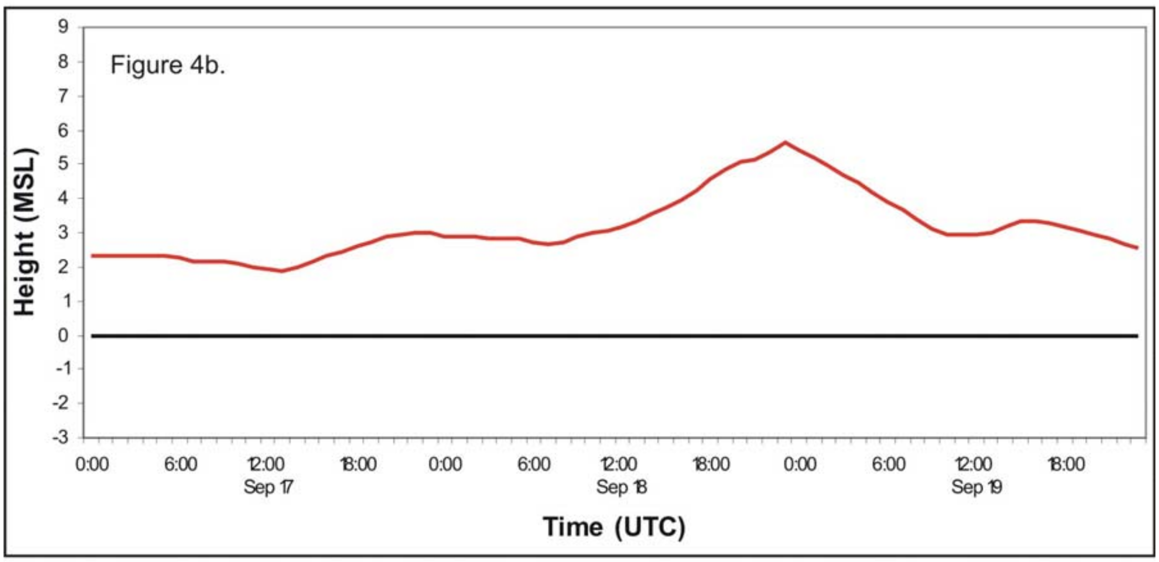


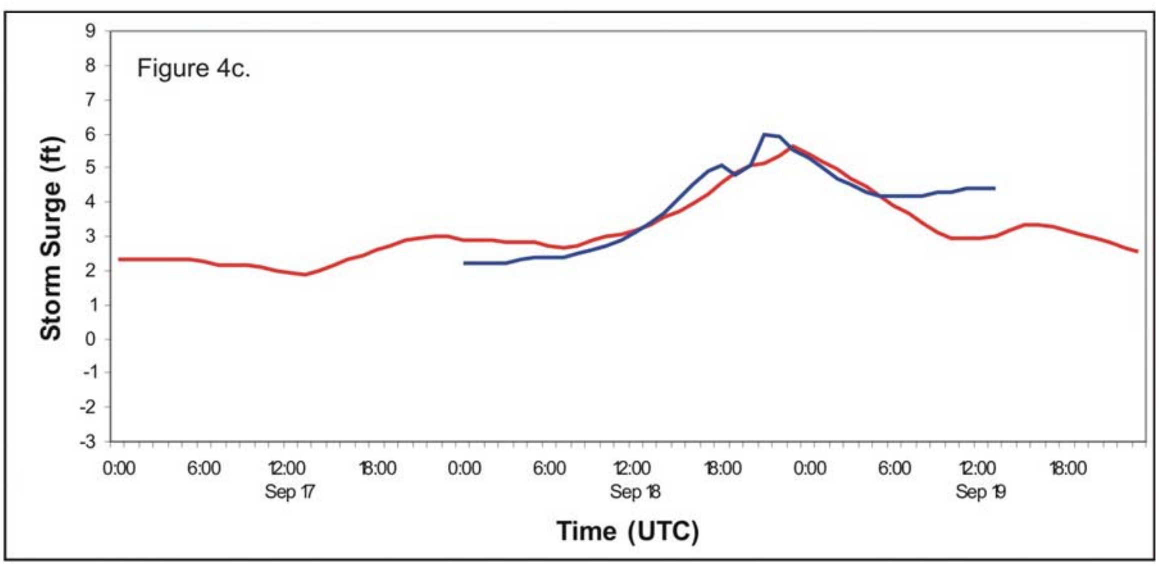
Oregon Inlet Marina, NC



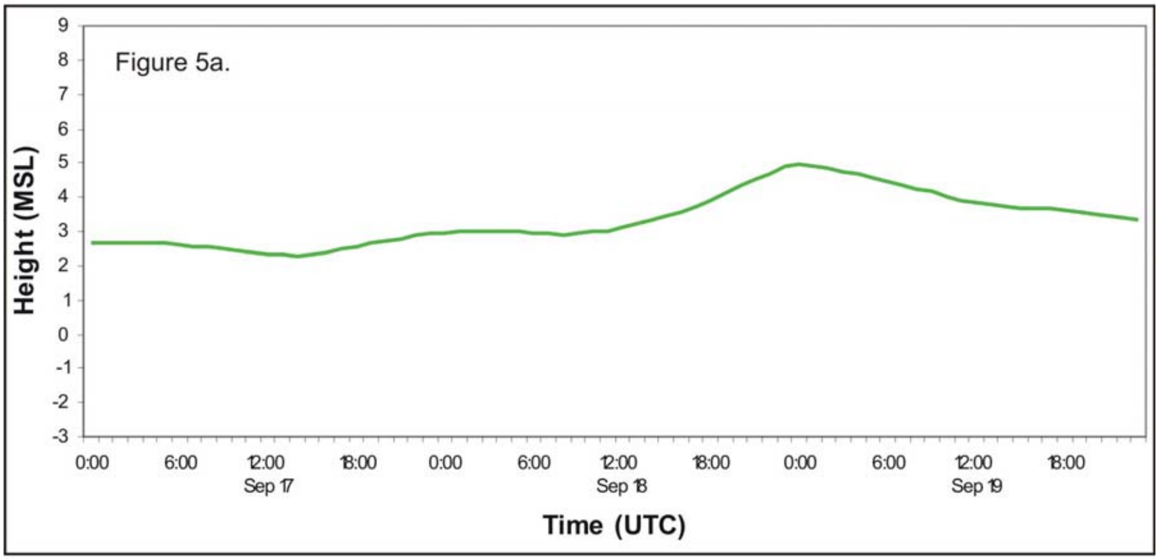
Pollockville, NC

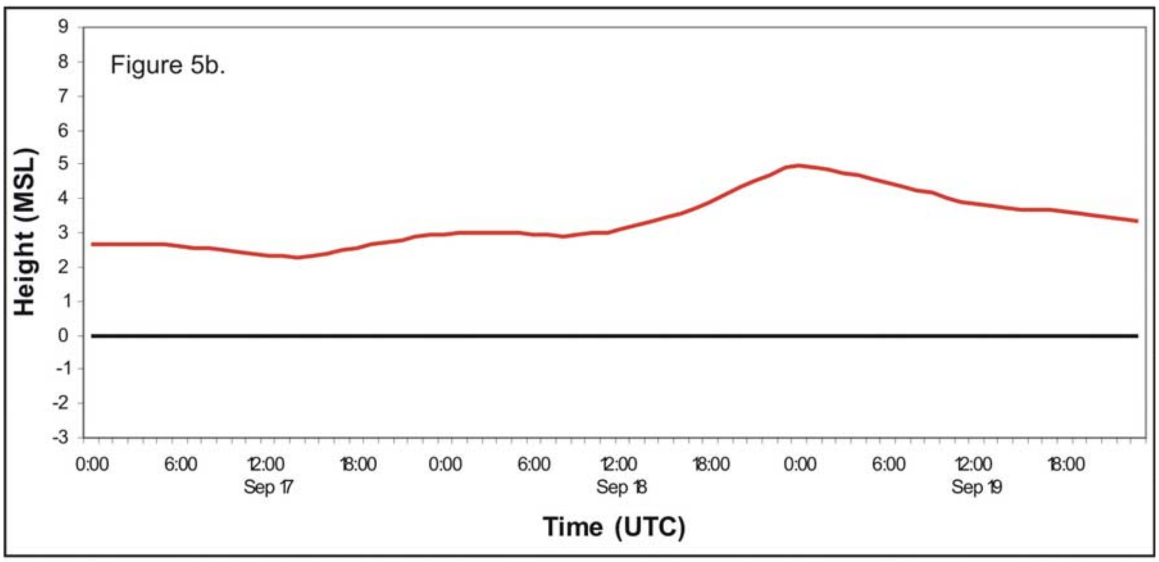


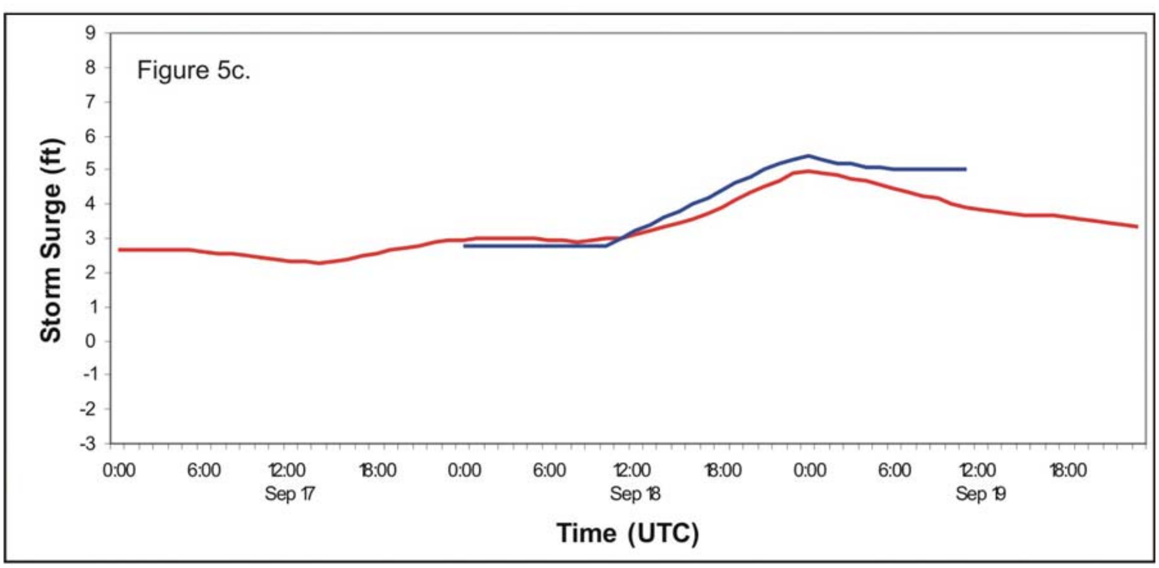




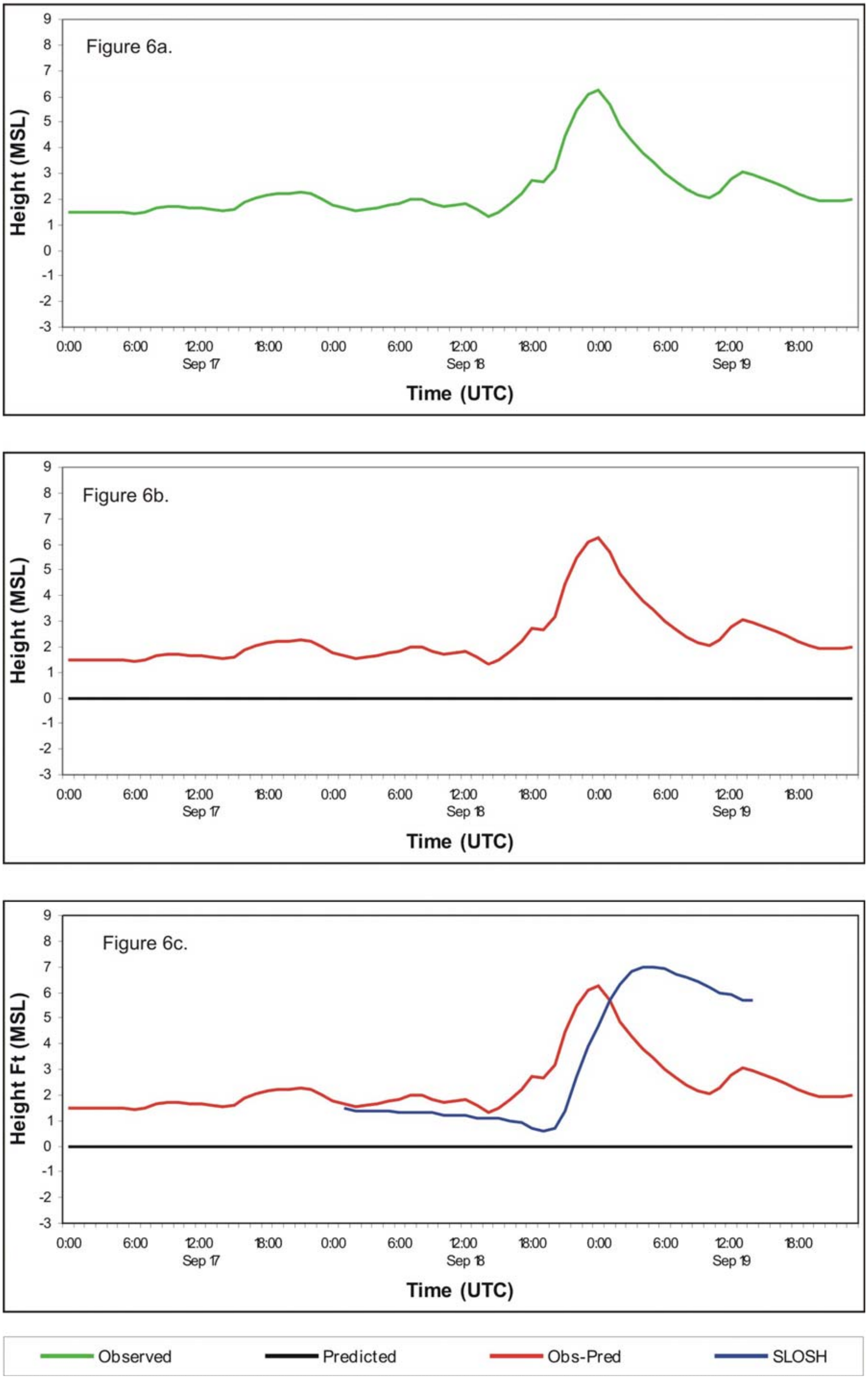
Swift Creek, NC



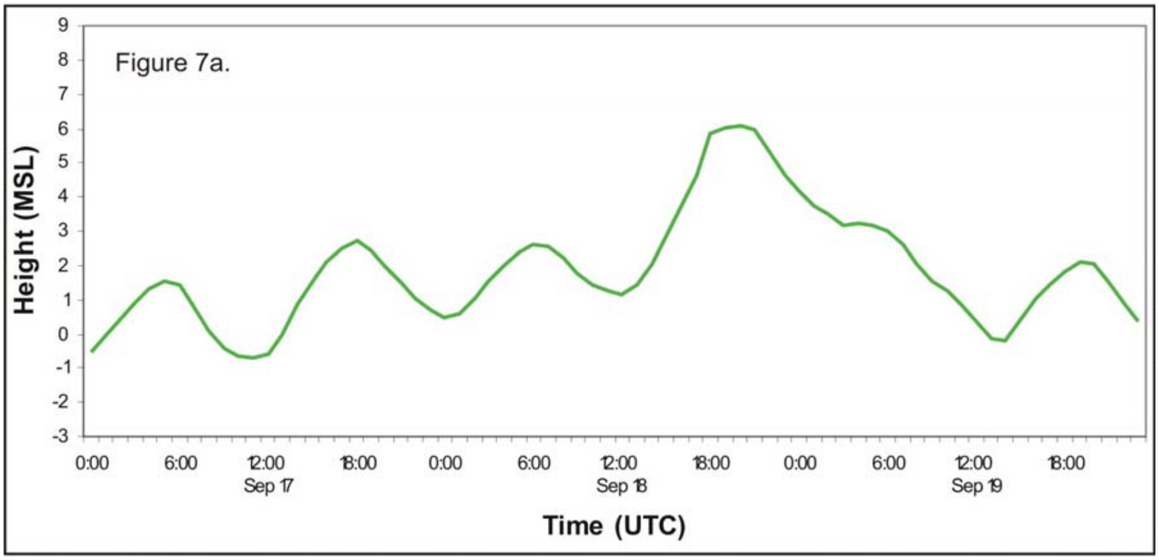


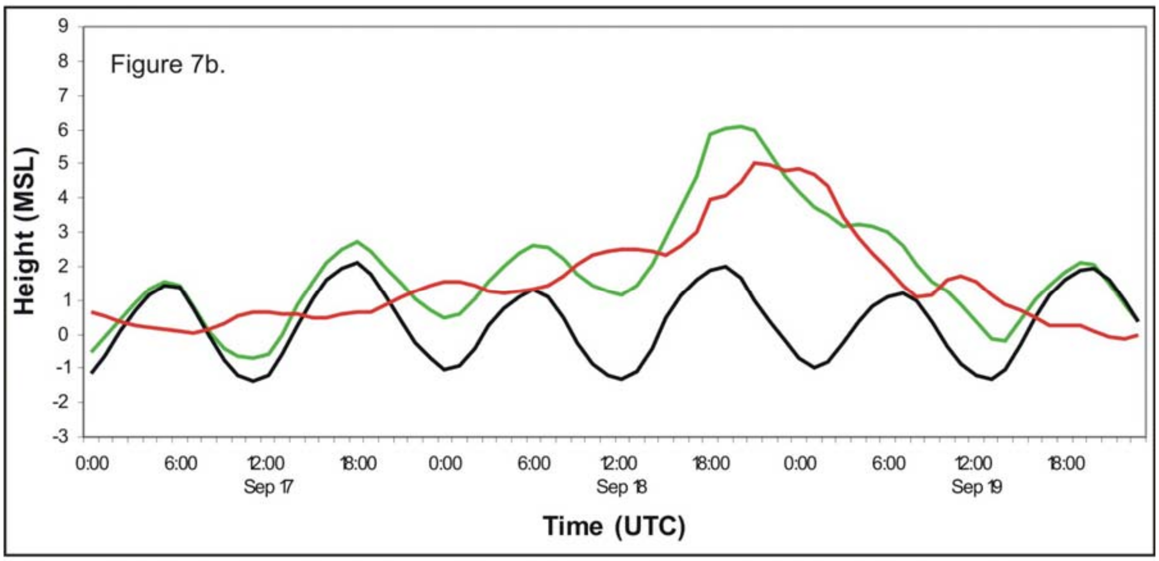


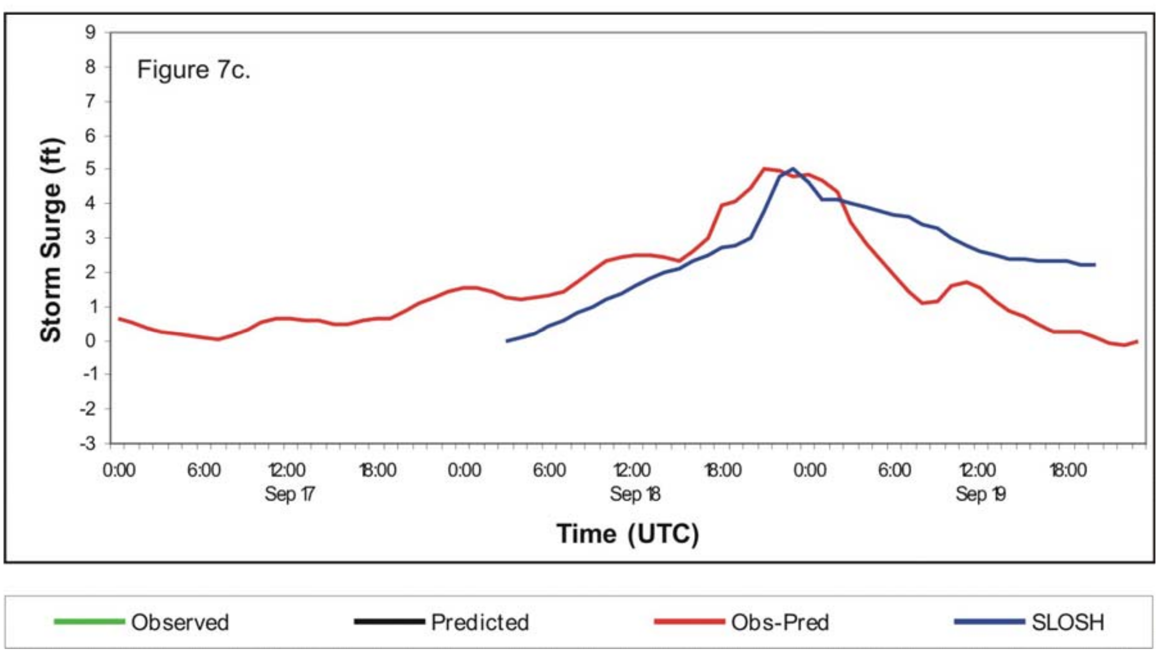
Washington, NC



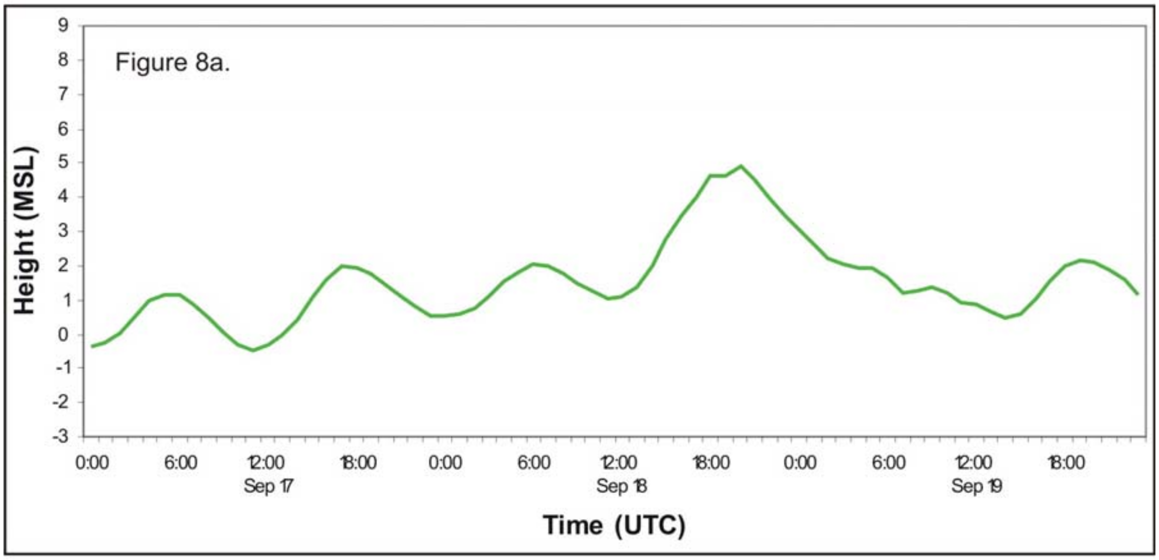
Wachapreague, VA

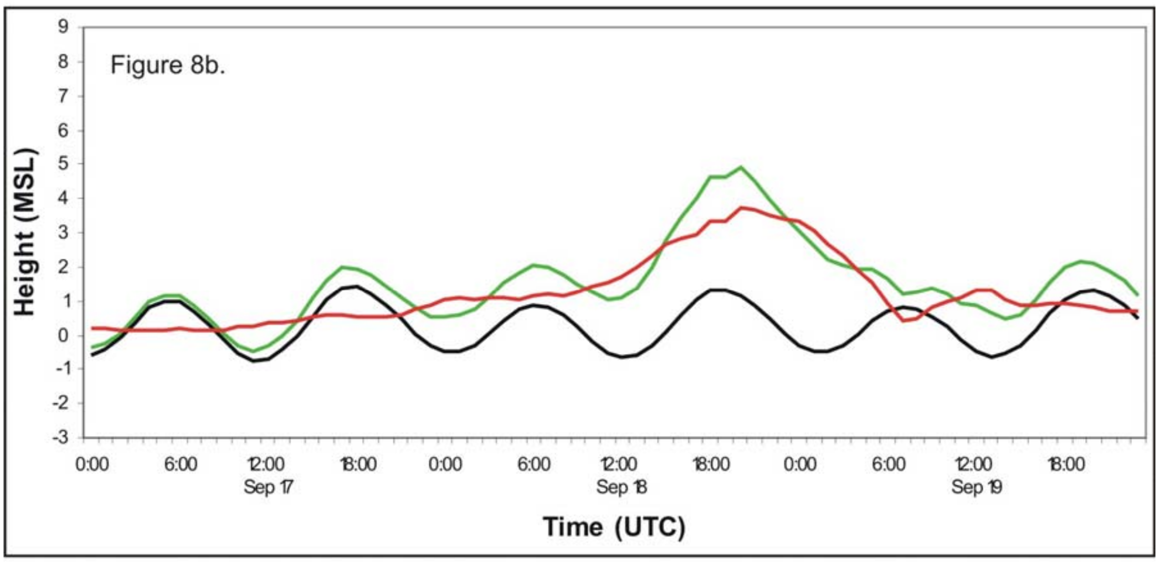


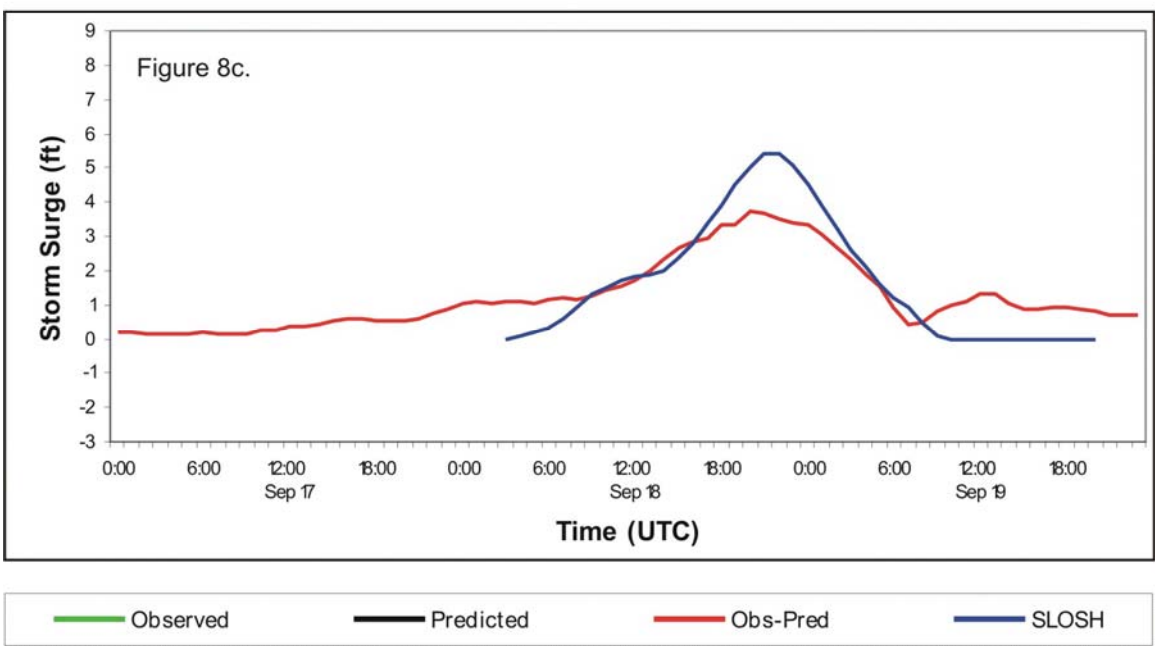




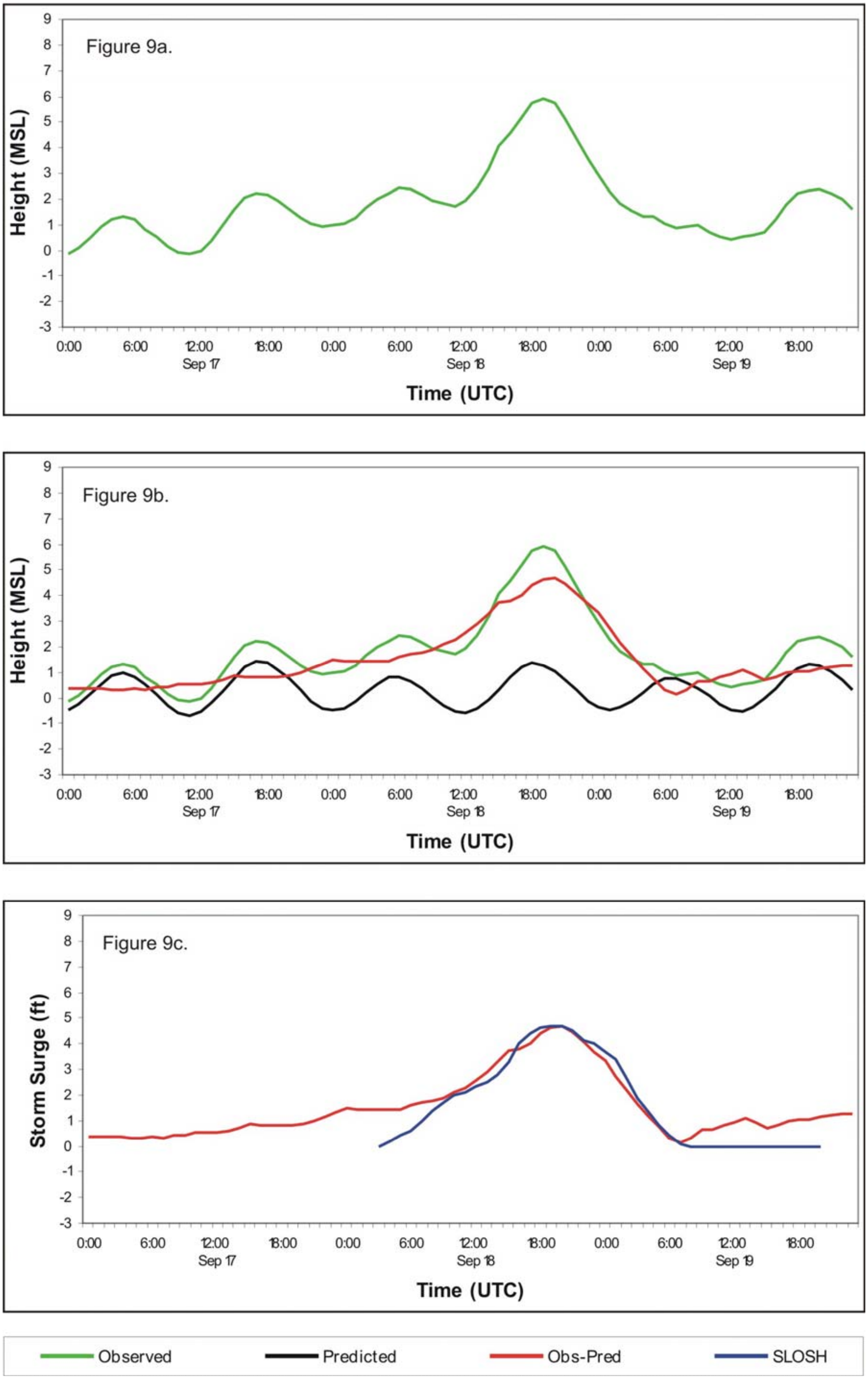
Kiptopeke, Chesapeake Bay, VA



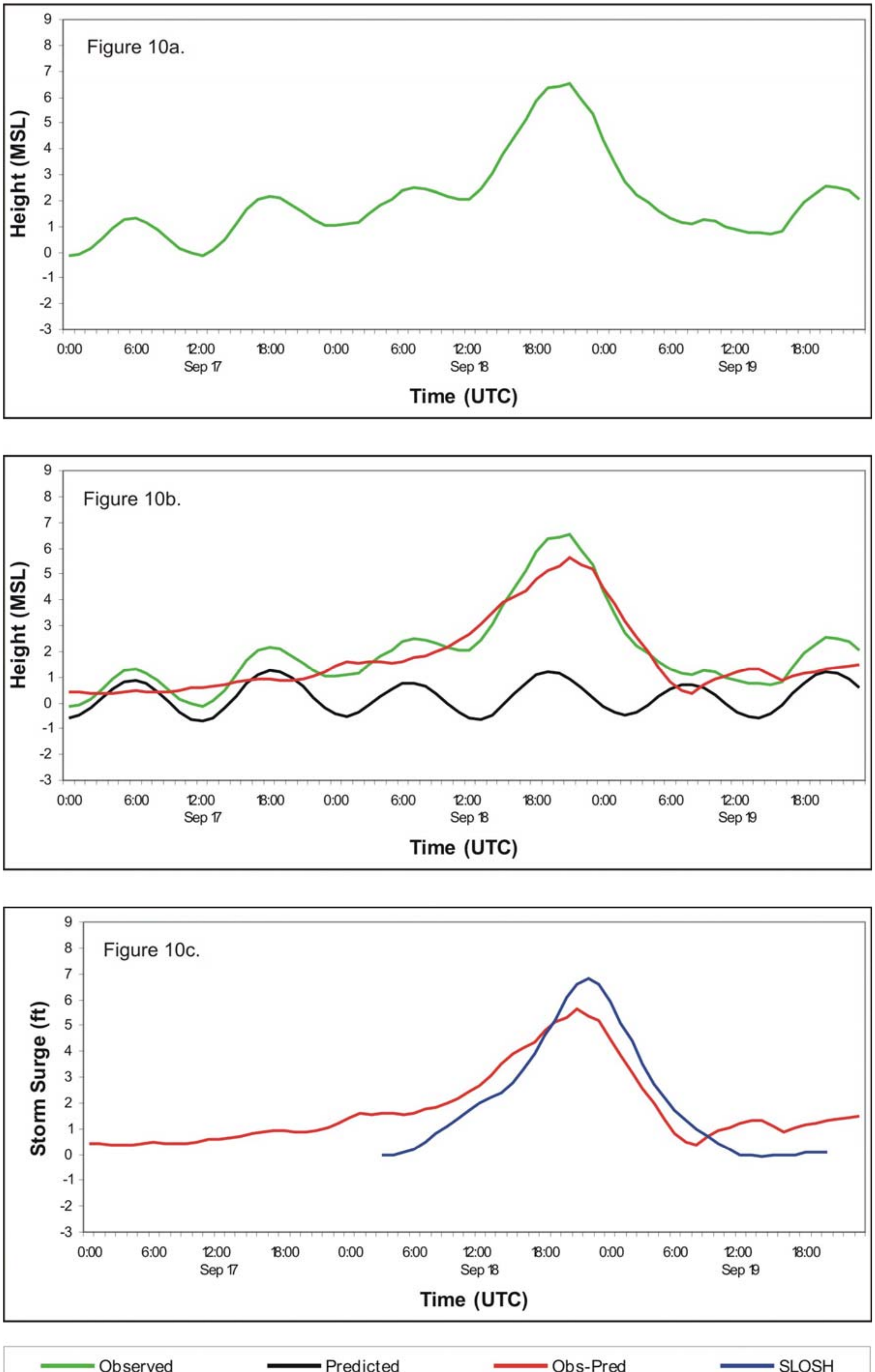




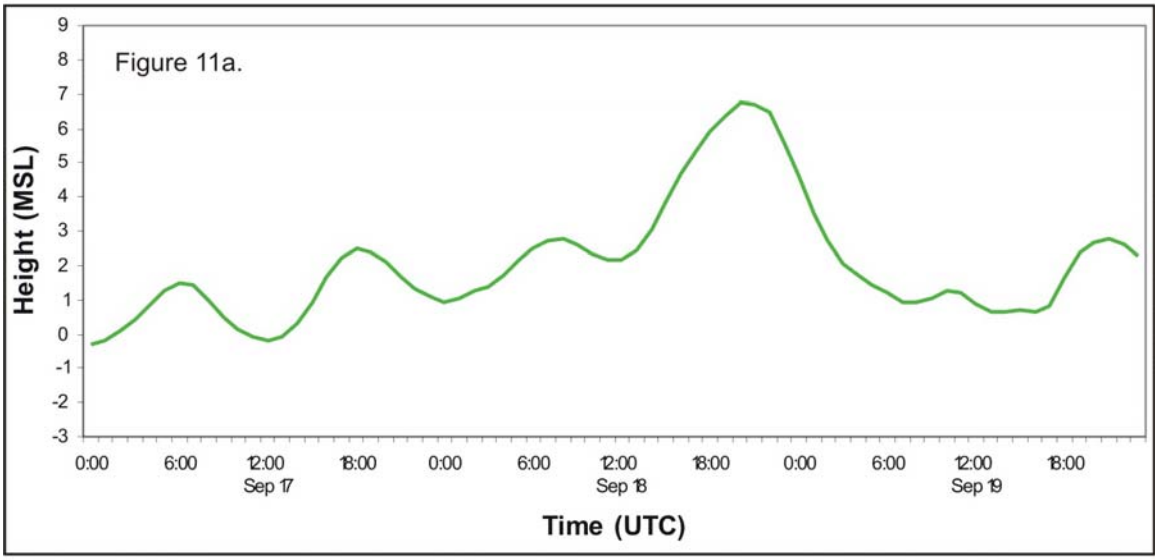
Chesapeake Bay Bridge Tunnel, VA

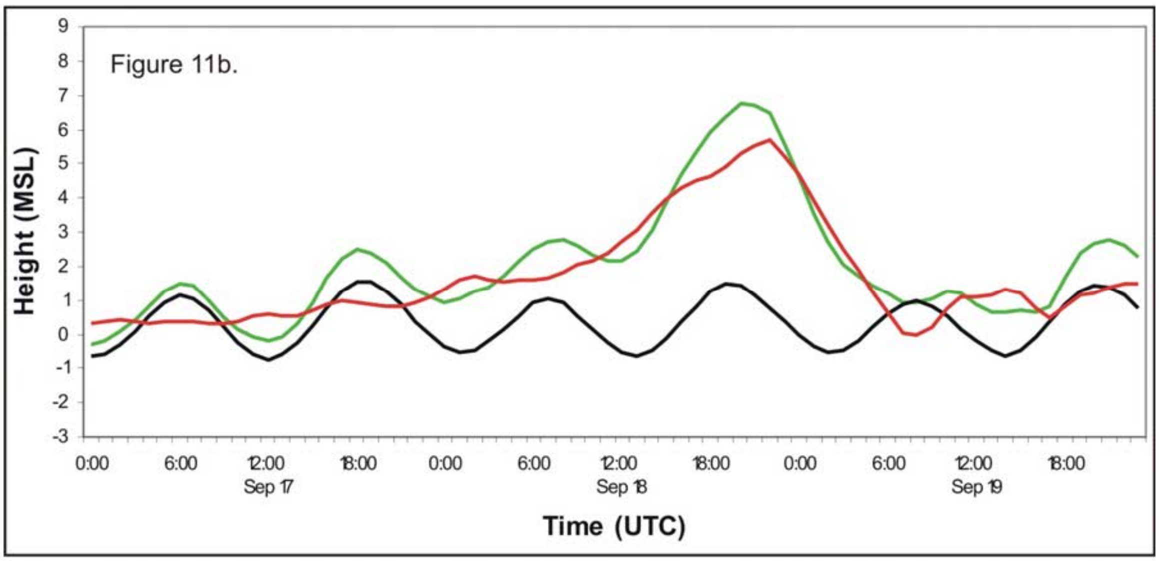


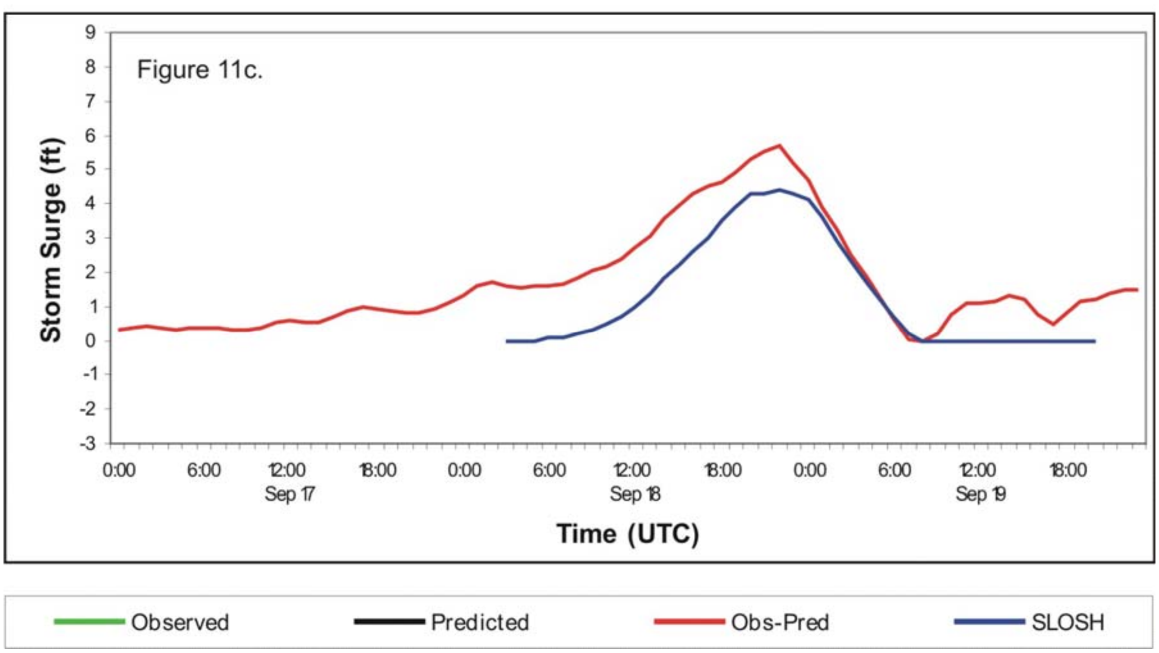
Sewells Point, VA



Money Point, Elizabeth River, VA







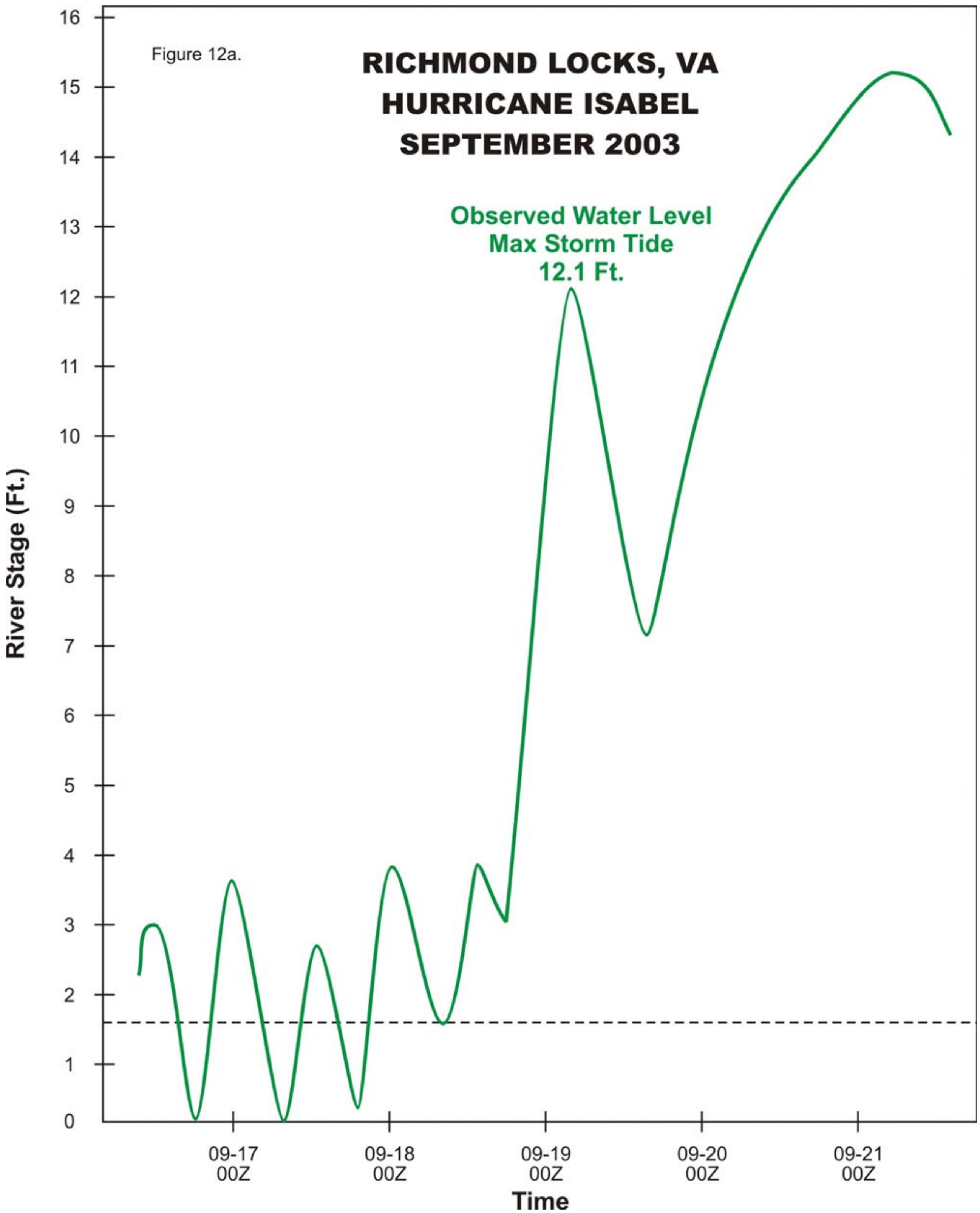


Figure 12a.
RICHMOND LOCKS, VA
HURRICANE ISABEL
SEPTEMBER 2003
Observed Water Level
Max Storm Tide
12.1 Ft.
River Stage (Ft.)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
09-17
00Z
09-18
00Z
09-19
00Z
09-20
00Z
09-21
00Z
Time

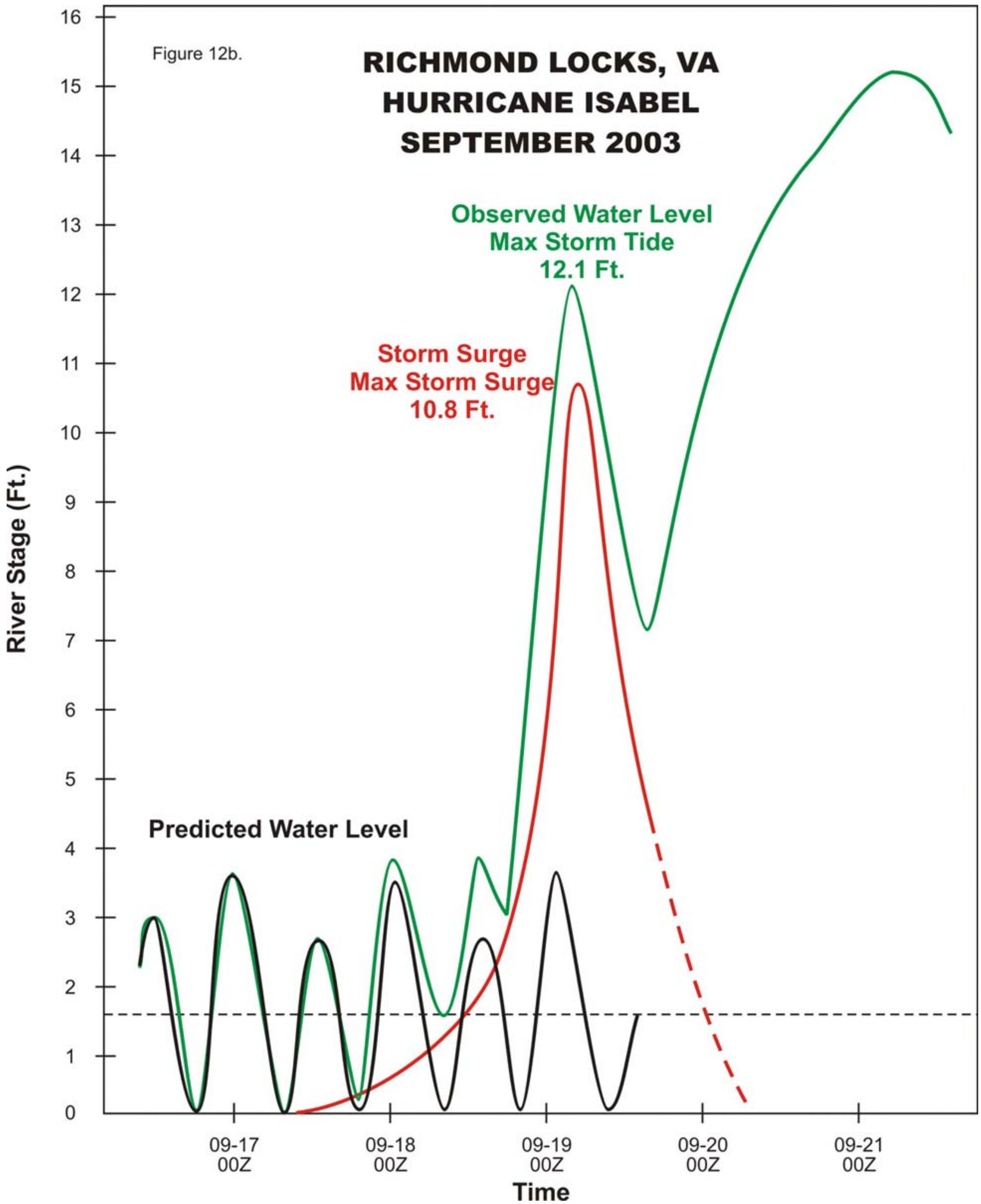


Figure 12b.
RICHMOND LOCKS, VA
HURRICANE ISABEL
SEPTEMBER 2003
Observed Water Level
Max Storm Tide
12.1 Ft.
Storm Surge
Max Storm Surge
10.8 Ft.
Predicted Water Level
River Stage (Ft.)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
09-17
00Z
09-18
00Z
09-19
00Z
09-20
00Z
09-21
00Z
Time

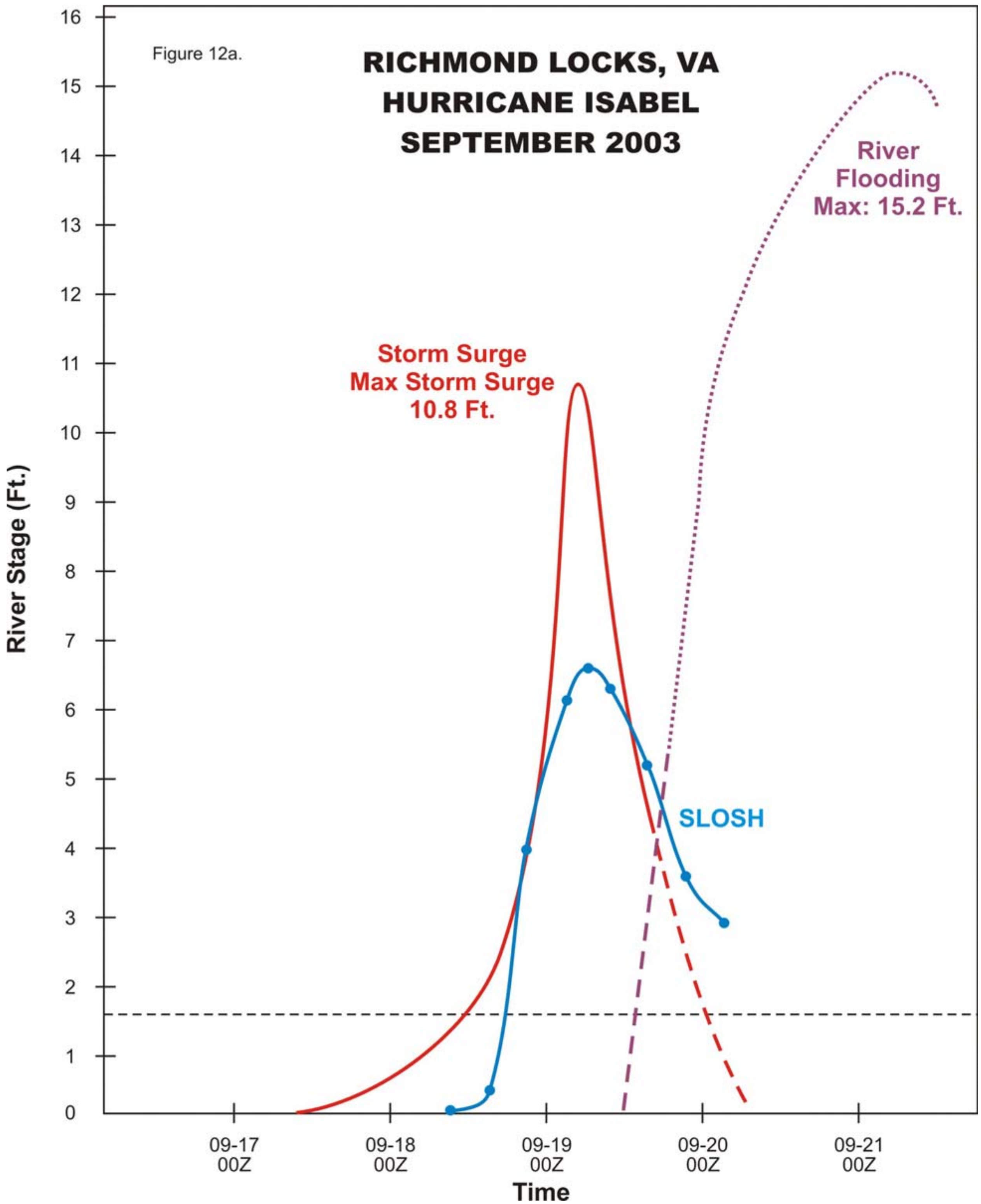
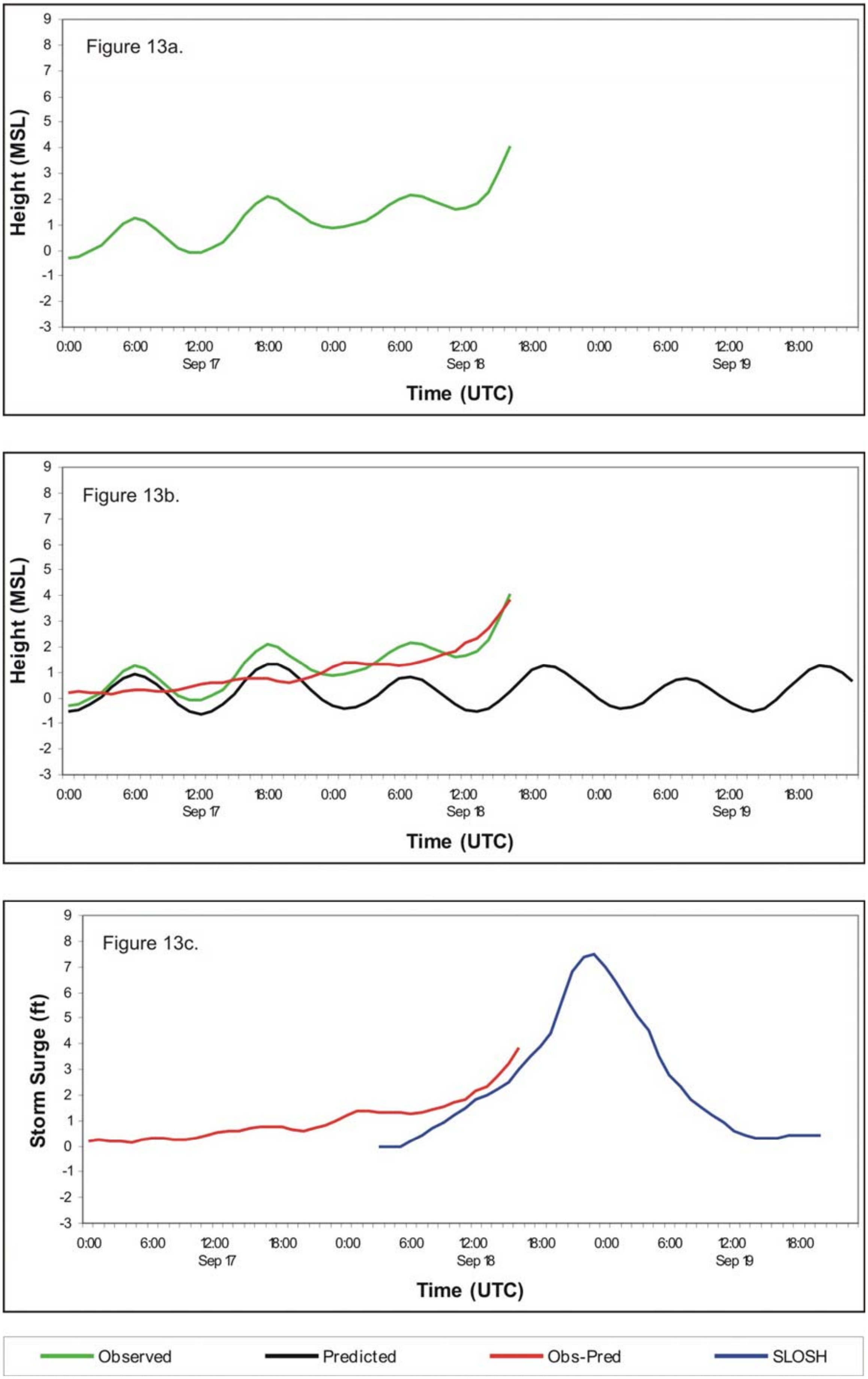
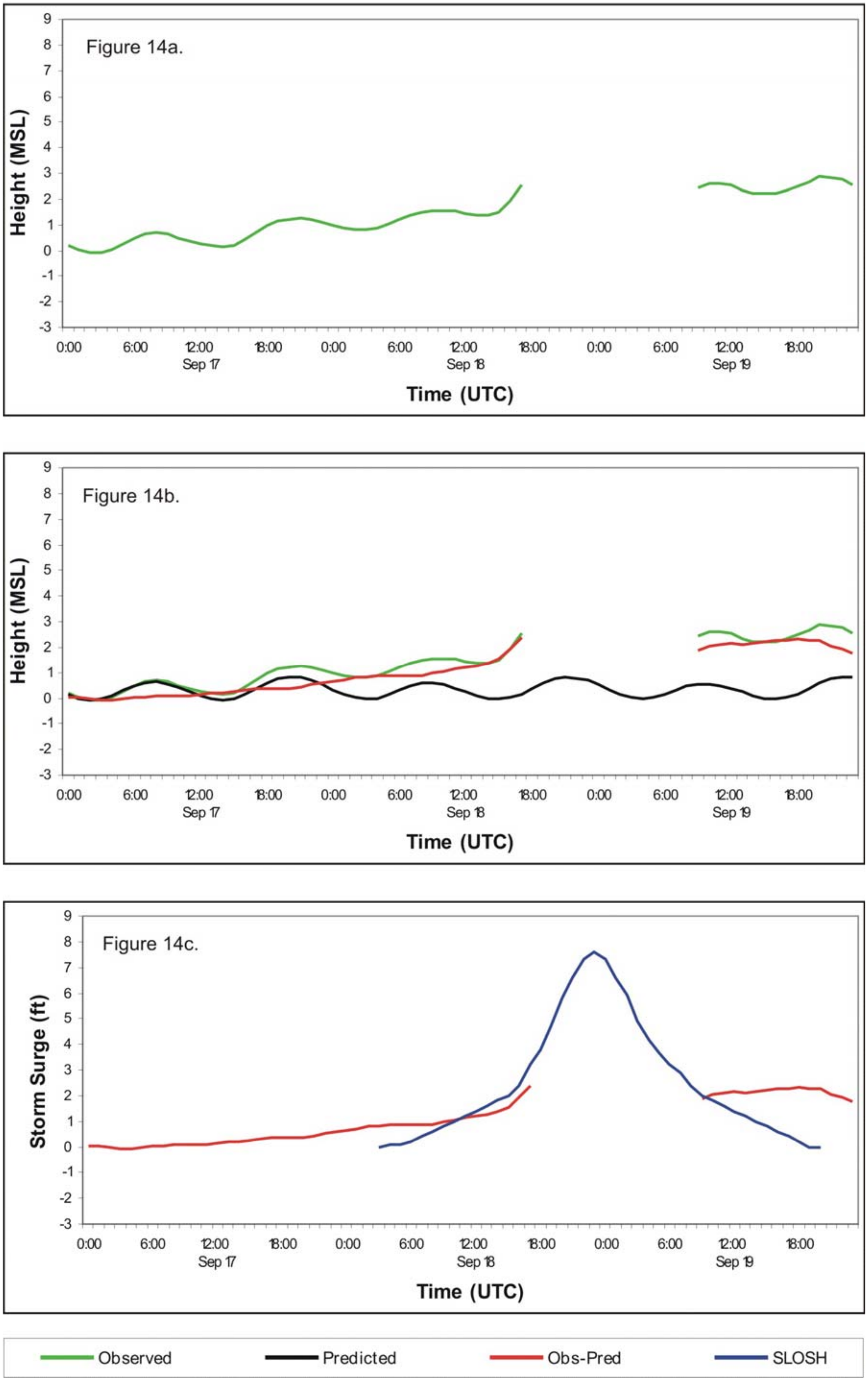


Figure 12a.
RICHMOND LOCKS, VA
HURRICANE ISABEL
SEPTEMBER 2003
River Stage (Ft.)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
River
Flooding
Max: 15.2 Ft.
Storm Surge
Max Storm Surge
10.8 Ft.
SLOSH
09-17
00Z
09-18
00Z
09-19
00Z
09-20
00Z
09-21
00Z
Time

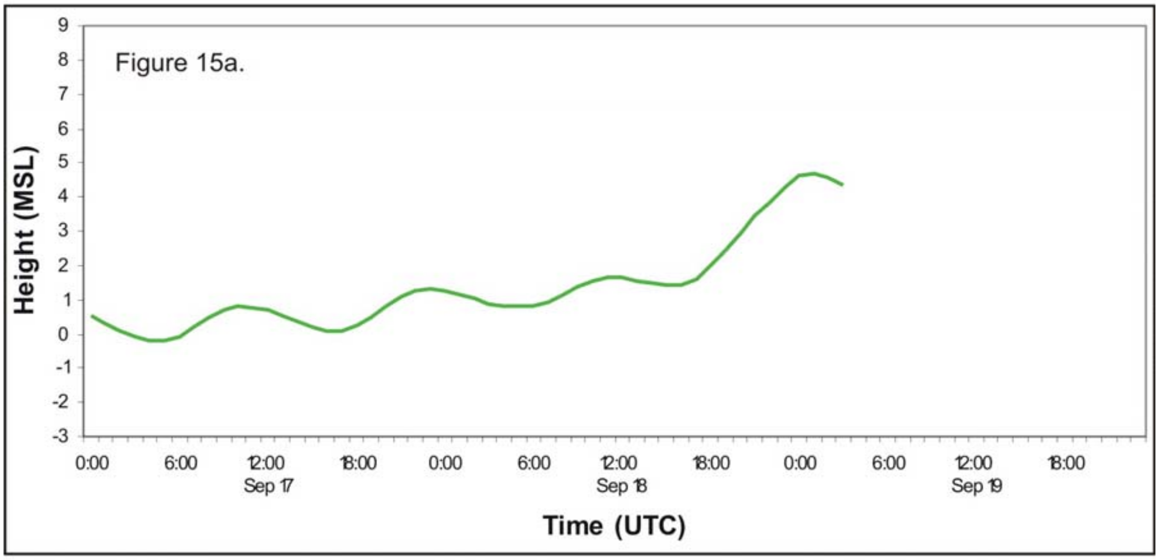
Gloucester Point, York River, VA

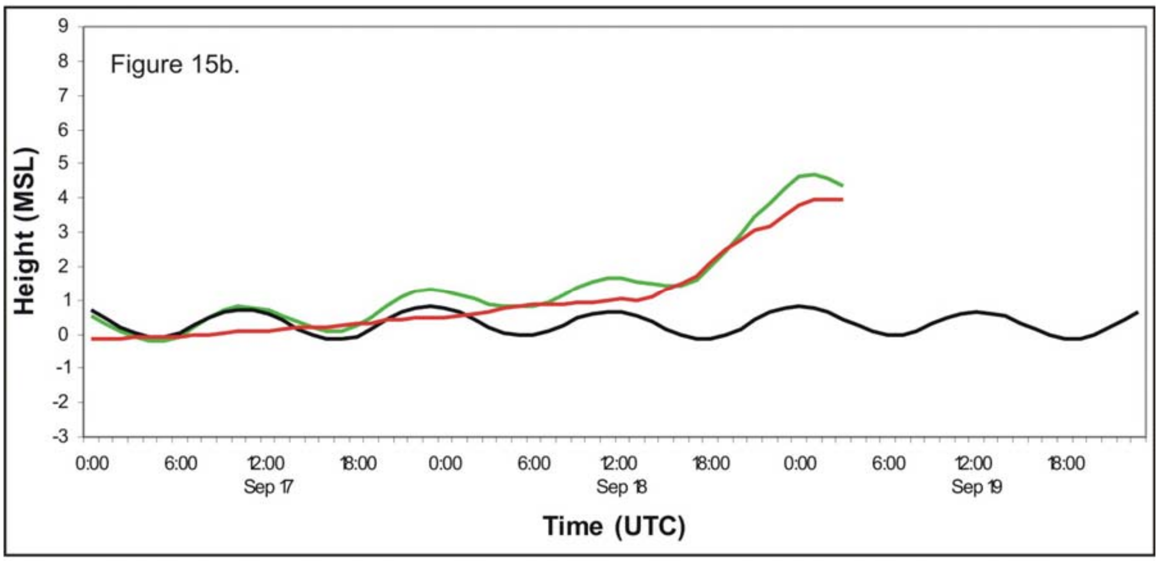


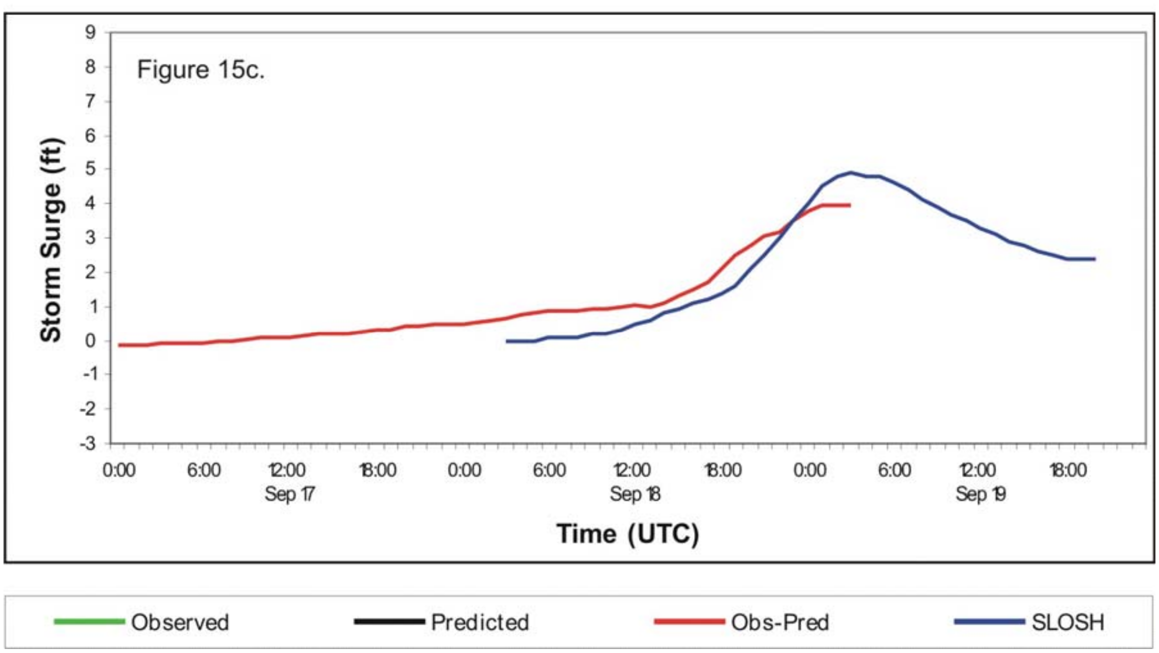
Windmill Point, VA



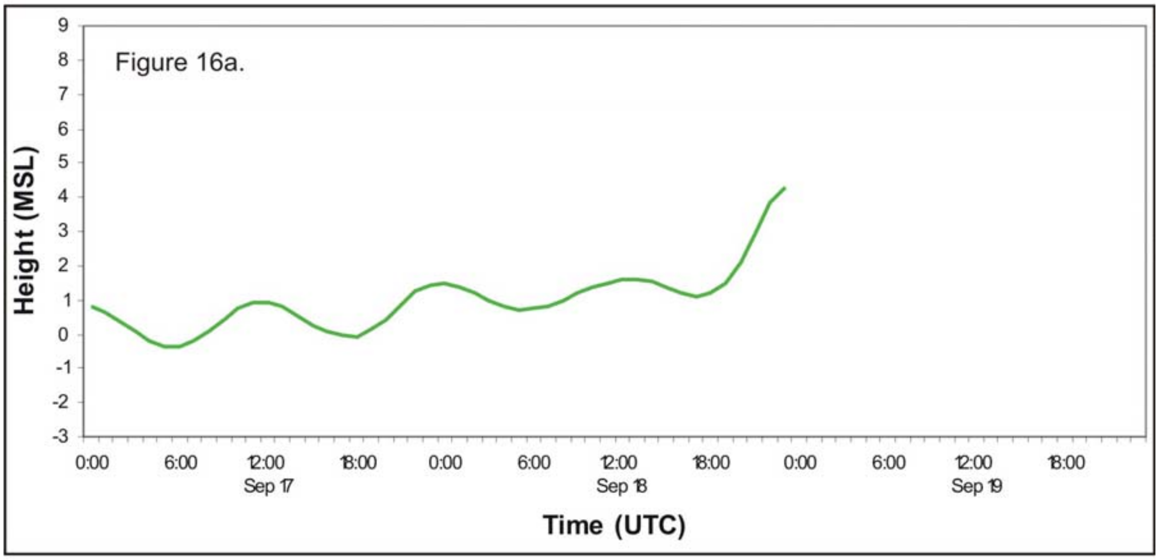
Lewisetta, Potomac River, VA

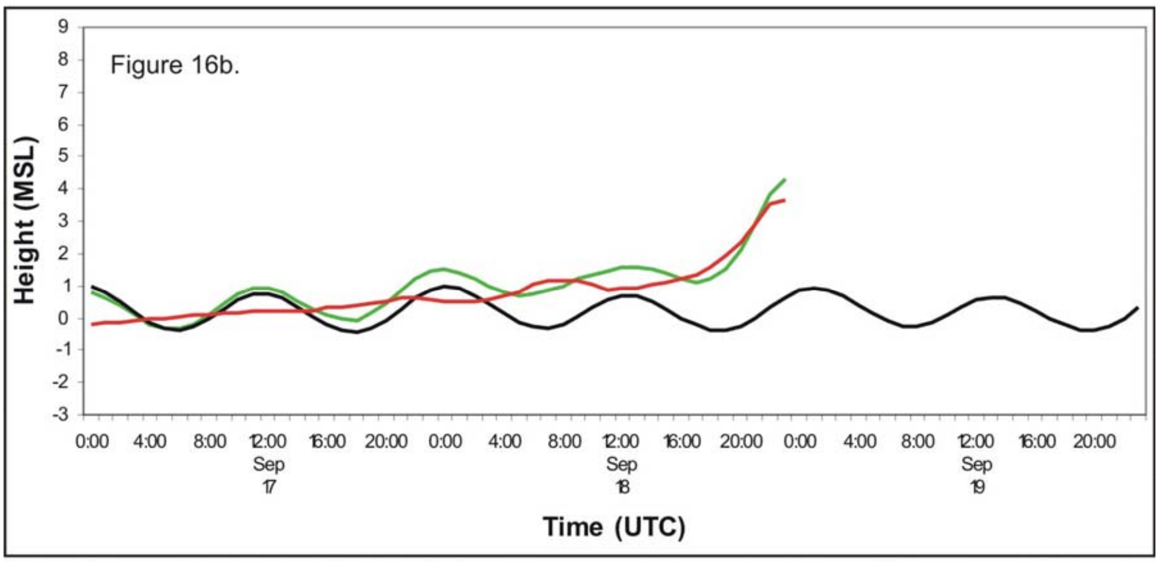


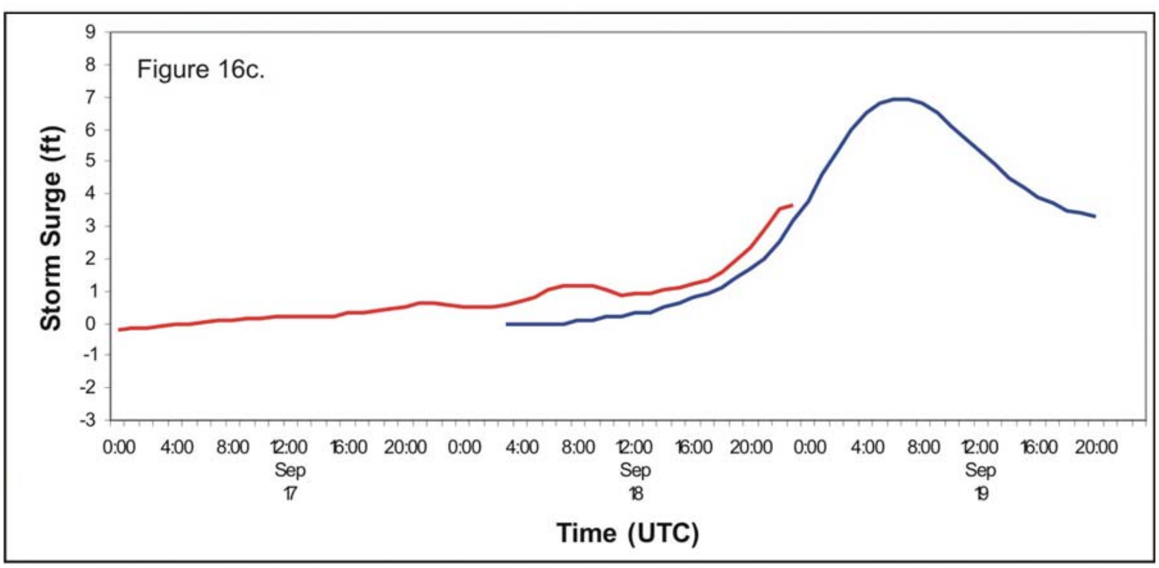




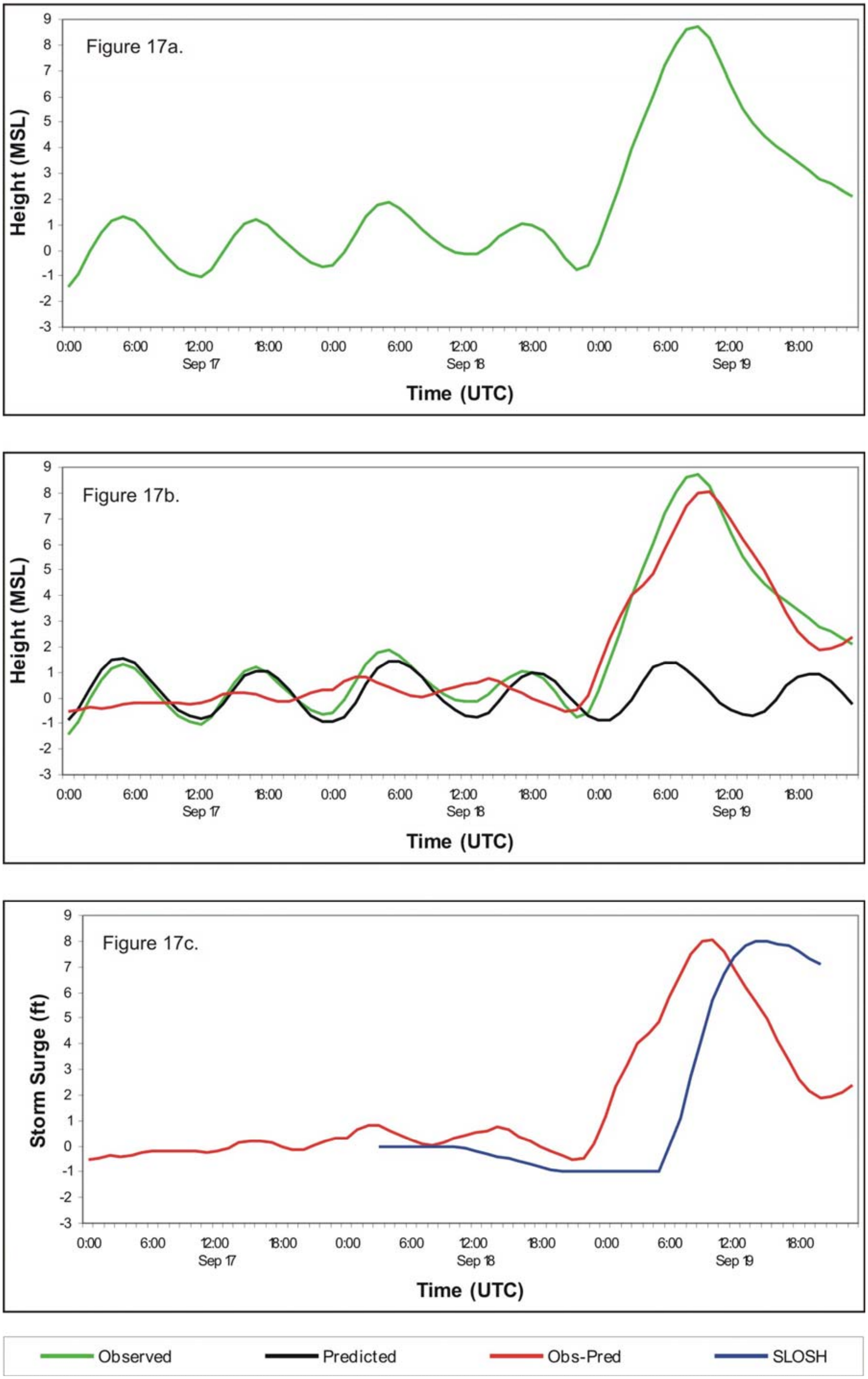
Colonial Beach, Potomac River, VA



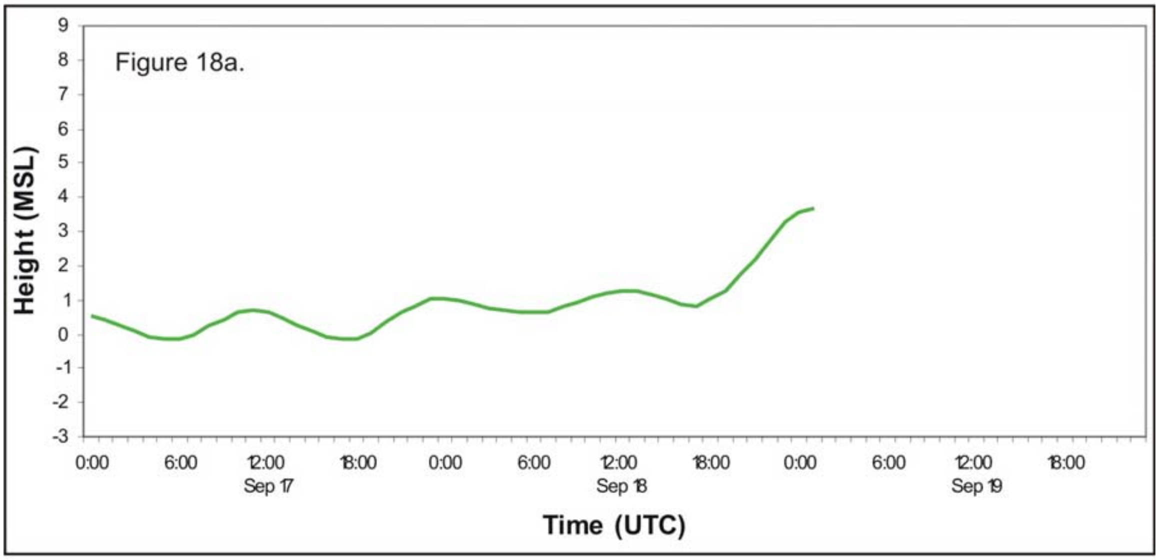


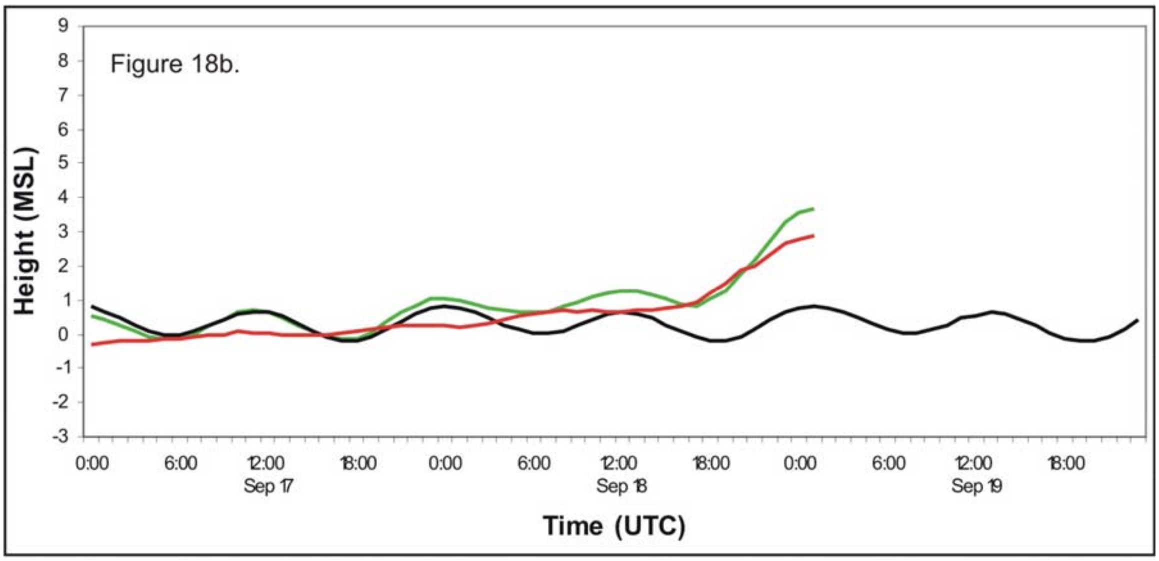


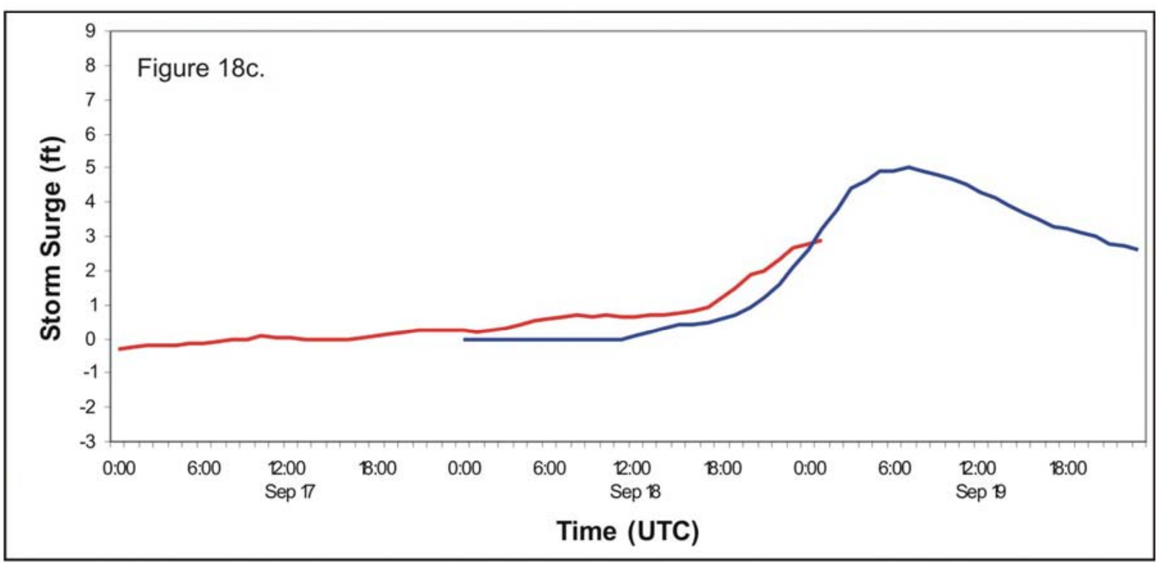
Washington, DC



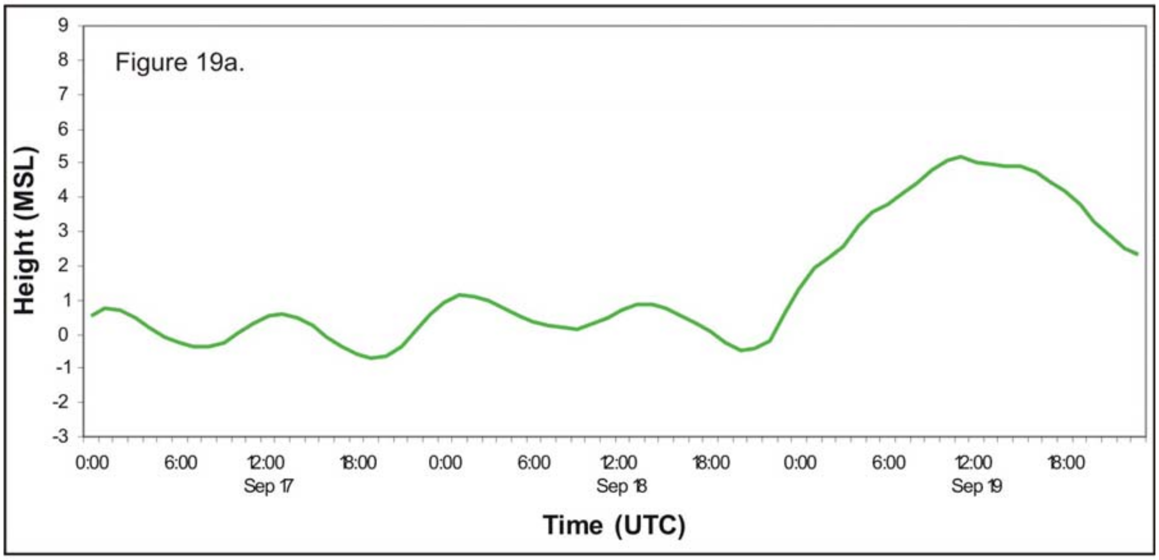
Solomon Island, MD

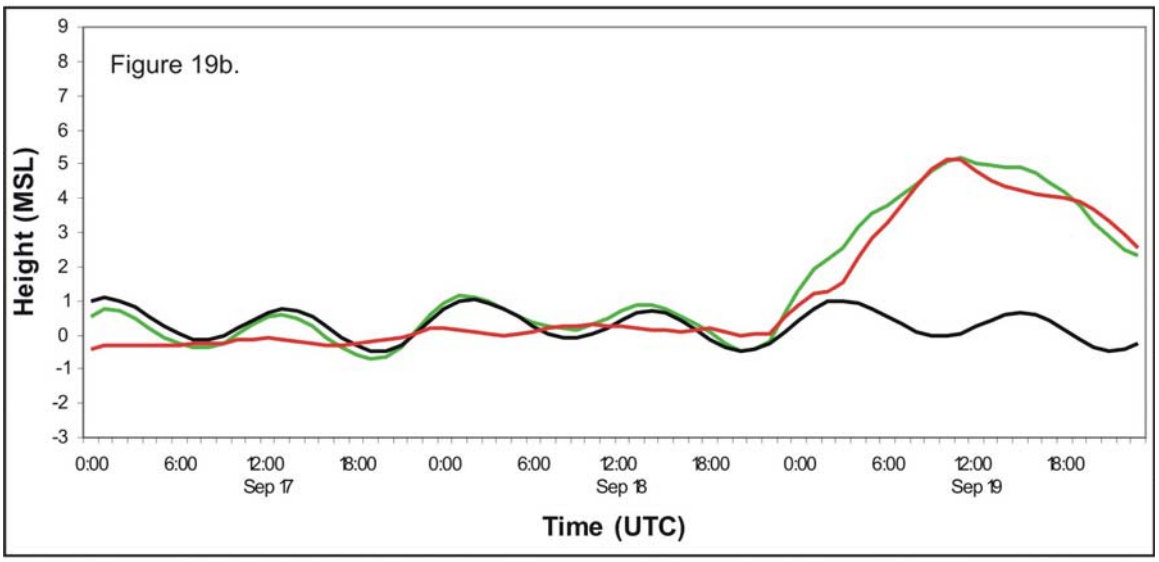


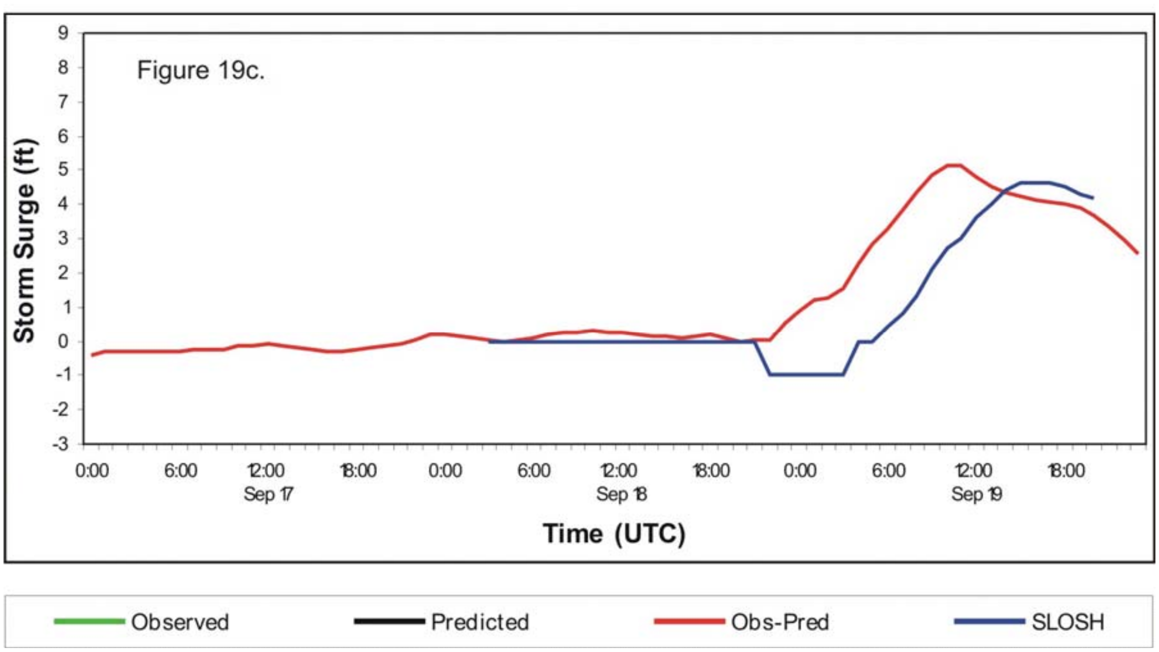




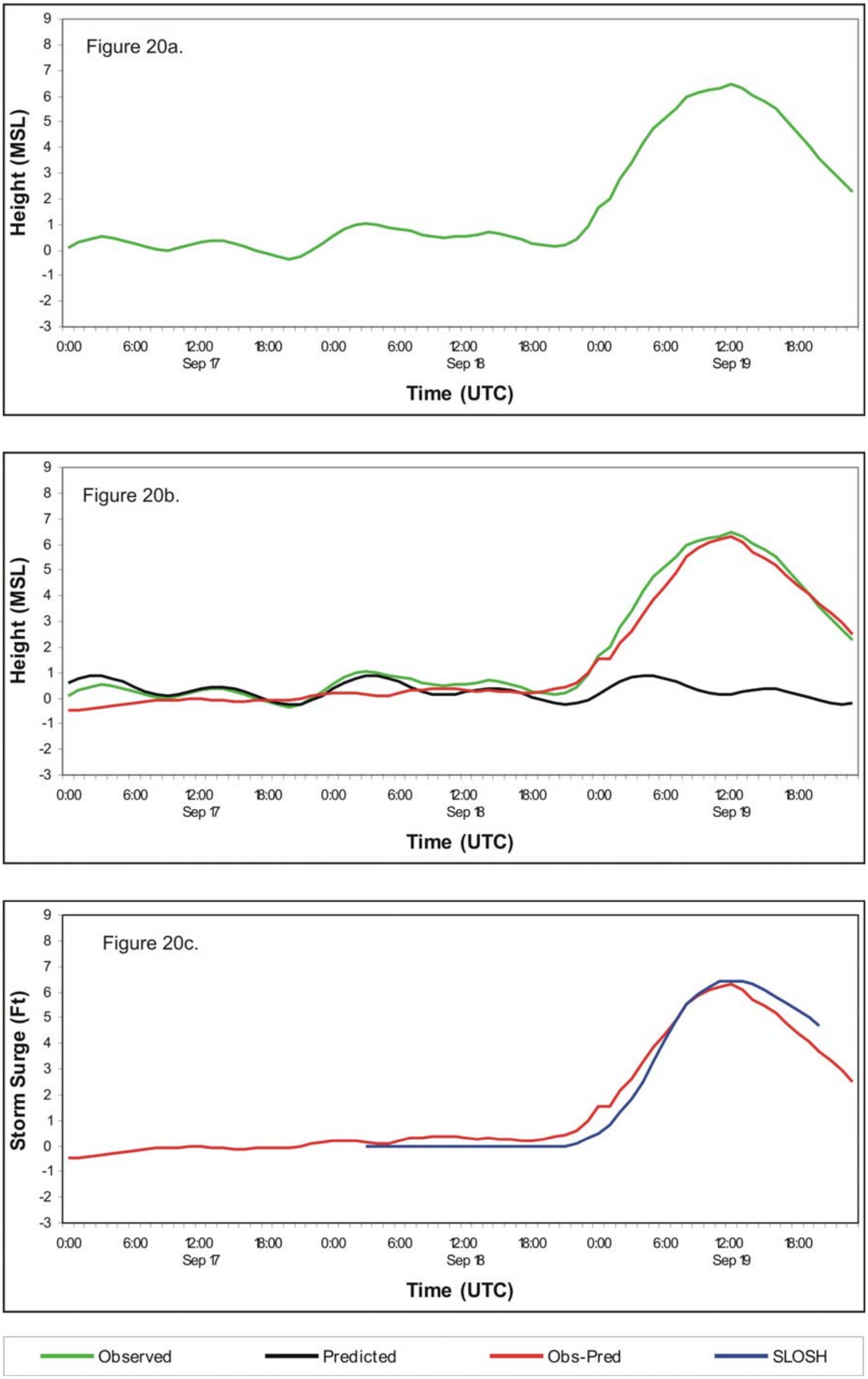
Cambridge, Choptank River, MD



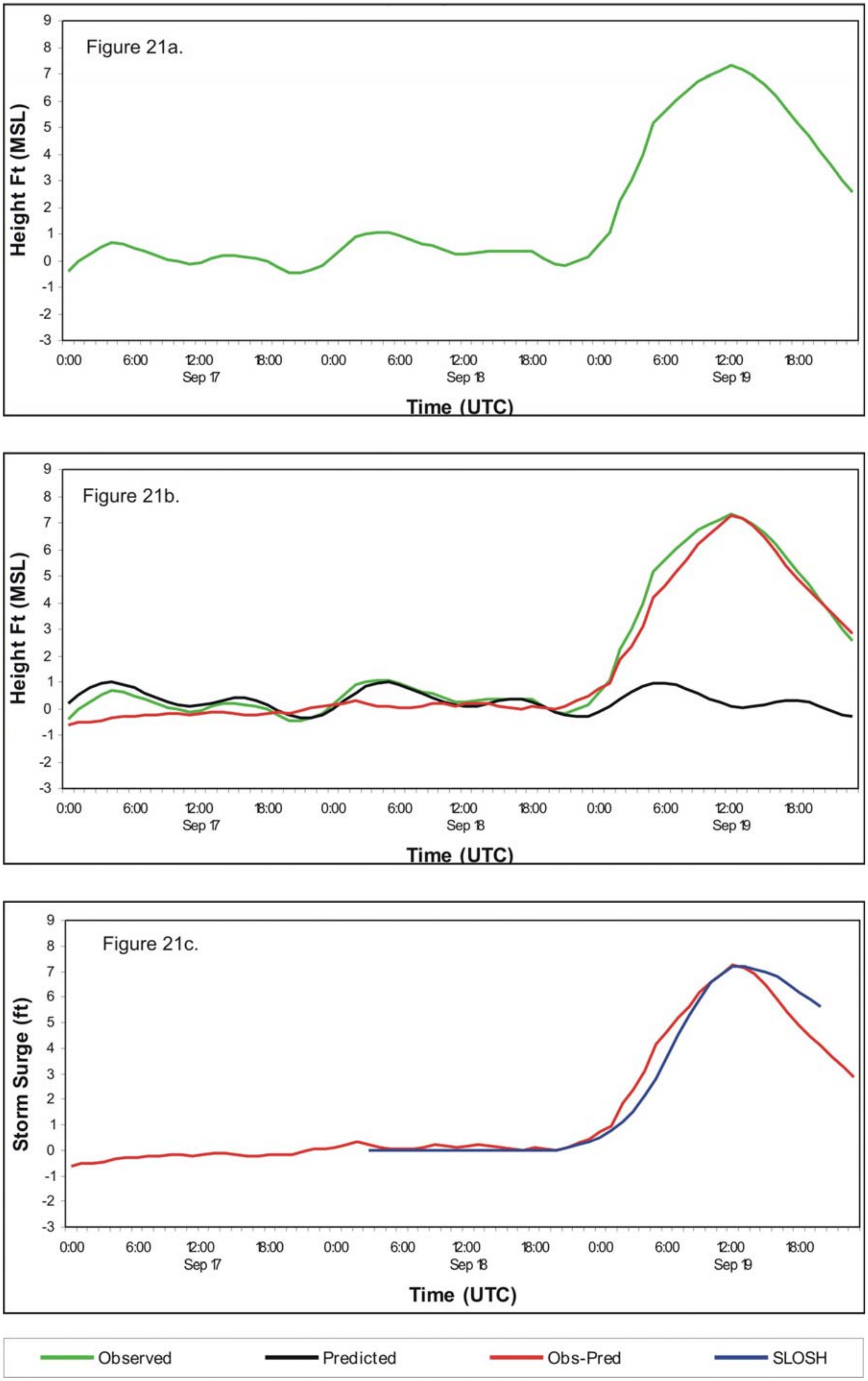




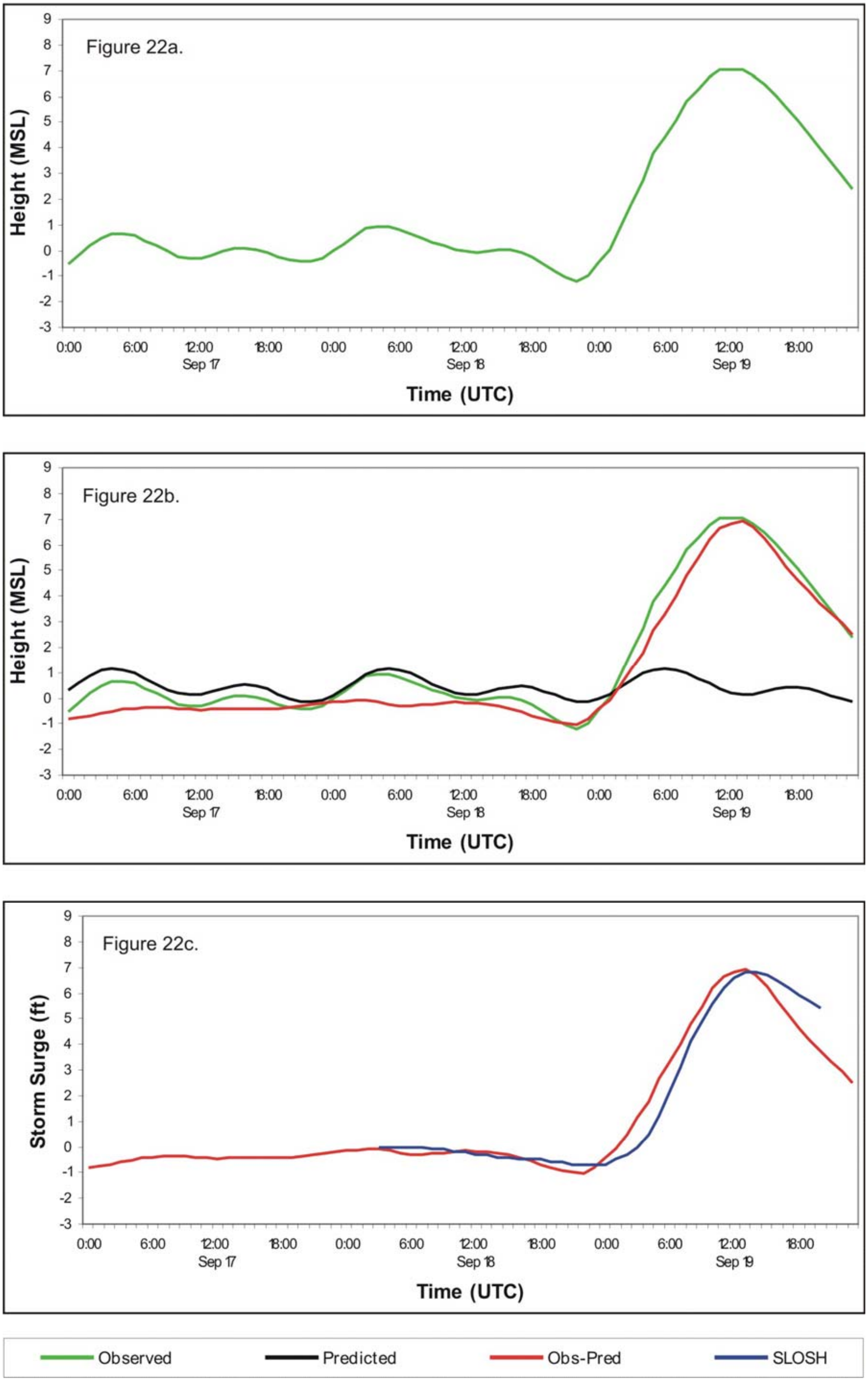
Annapolis, US Naval Academy, MD



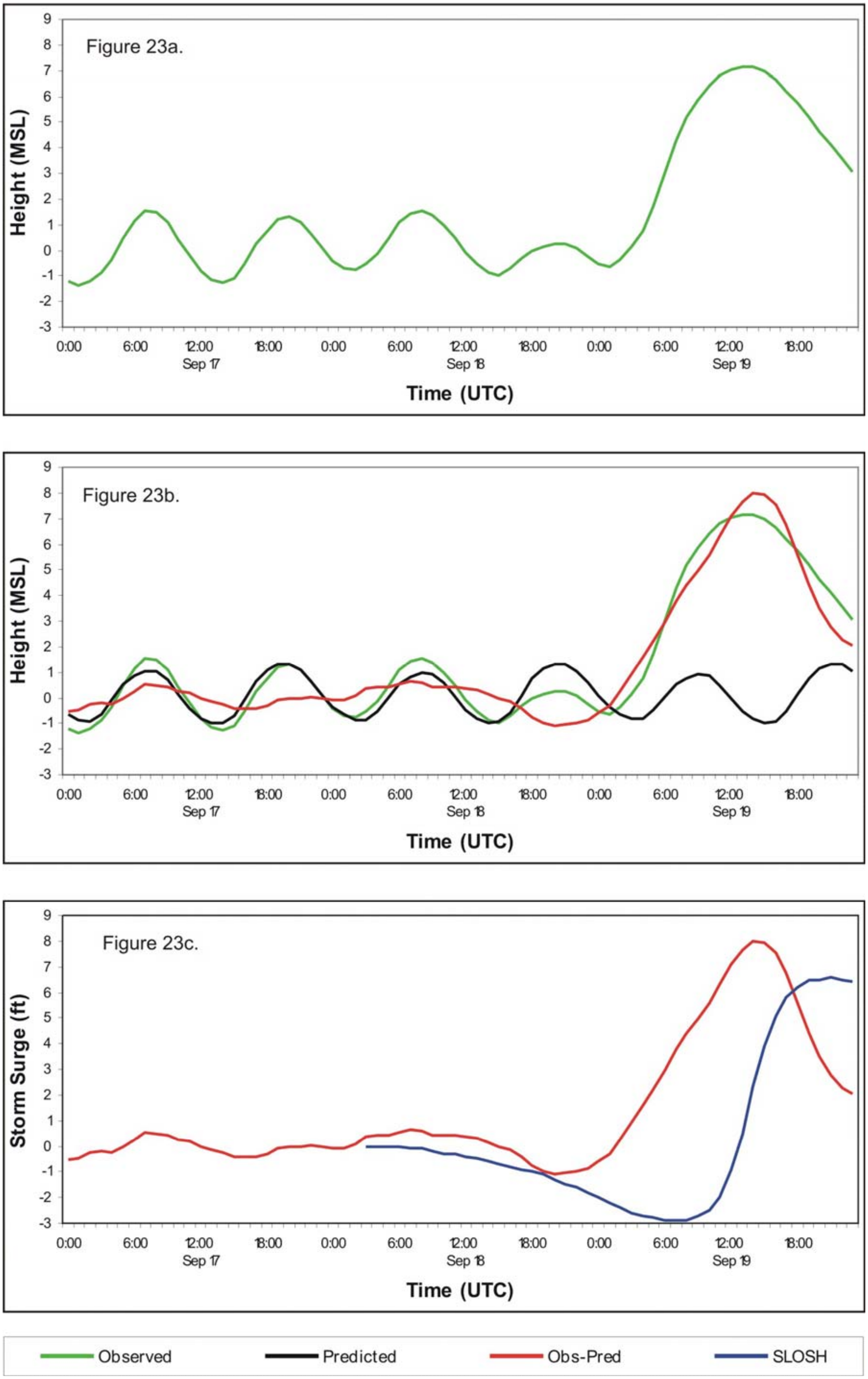
Baltimore, MD



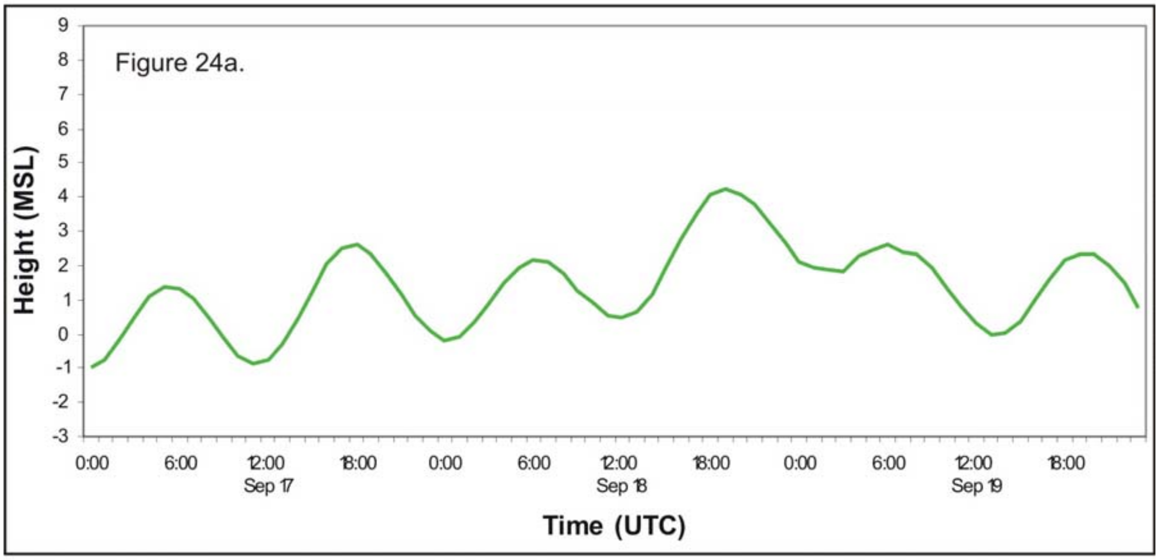
Tolchester Beach, MD

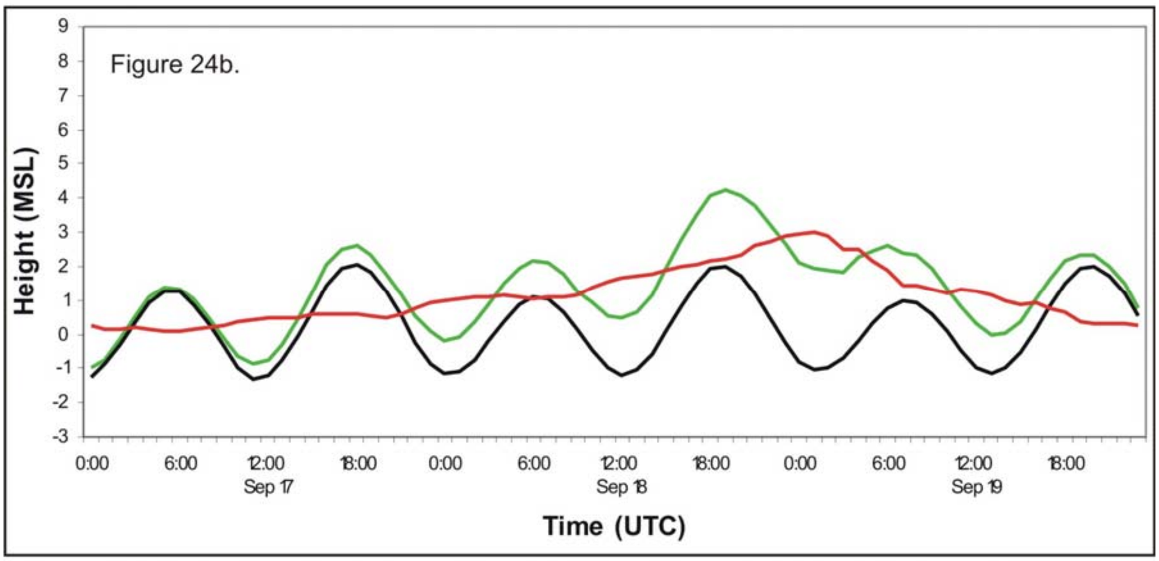


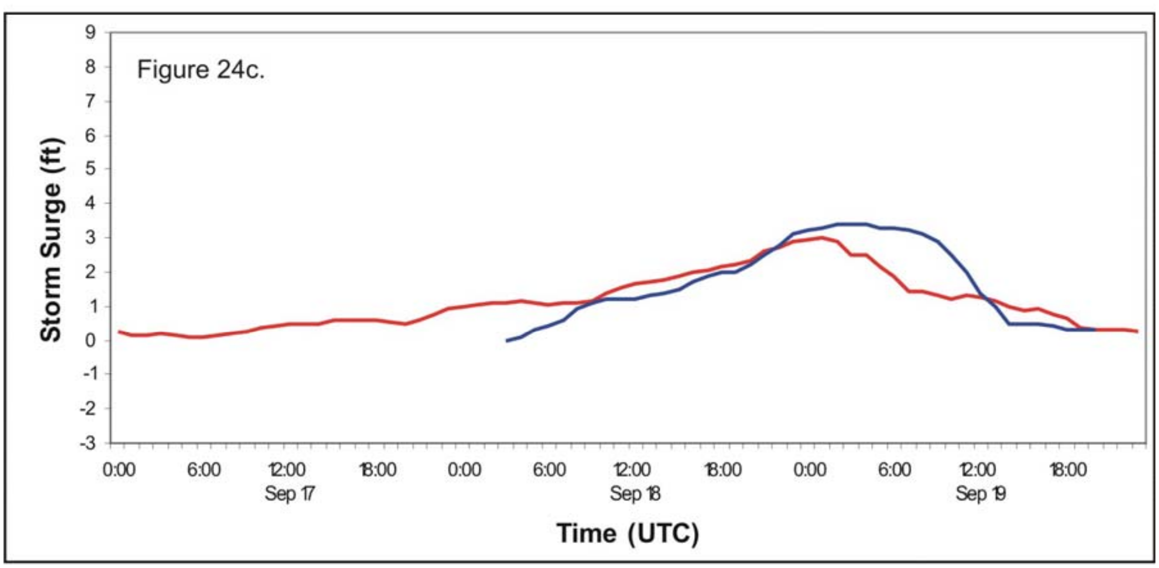
Chesapeake City, MD



Lewes, DE

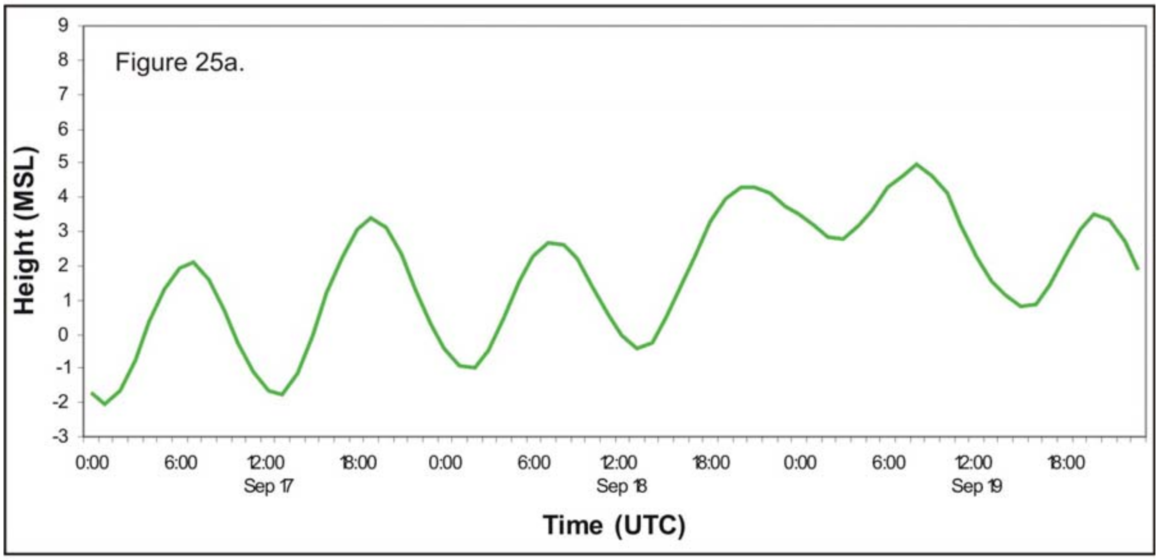


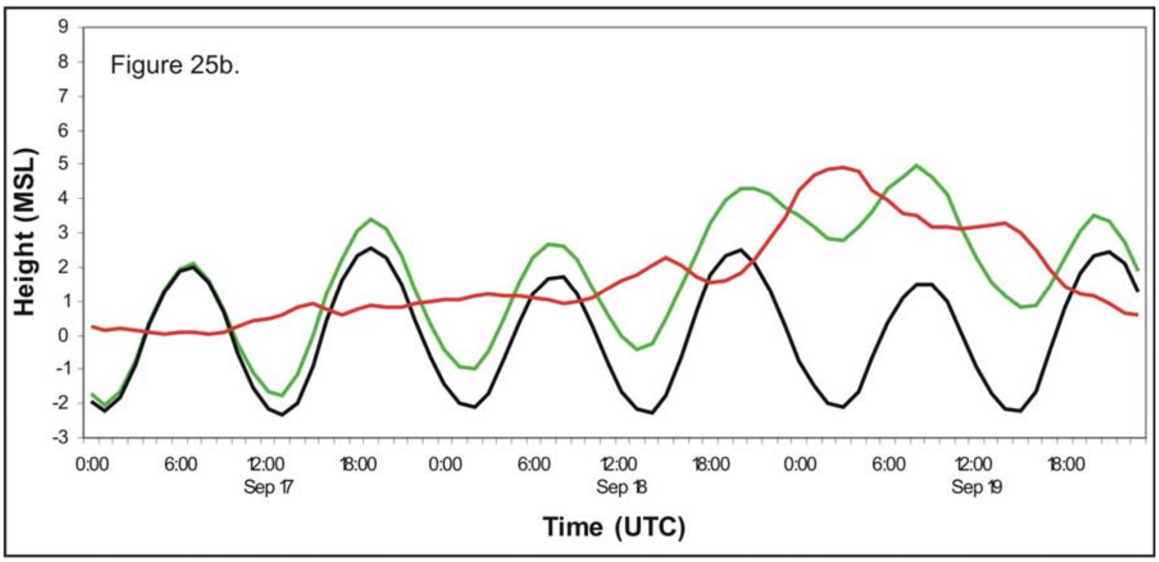


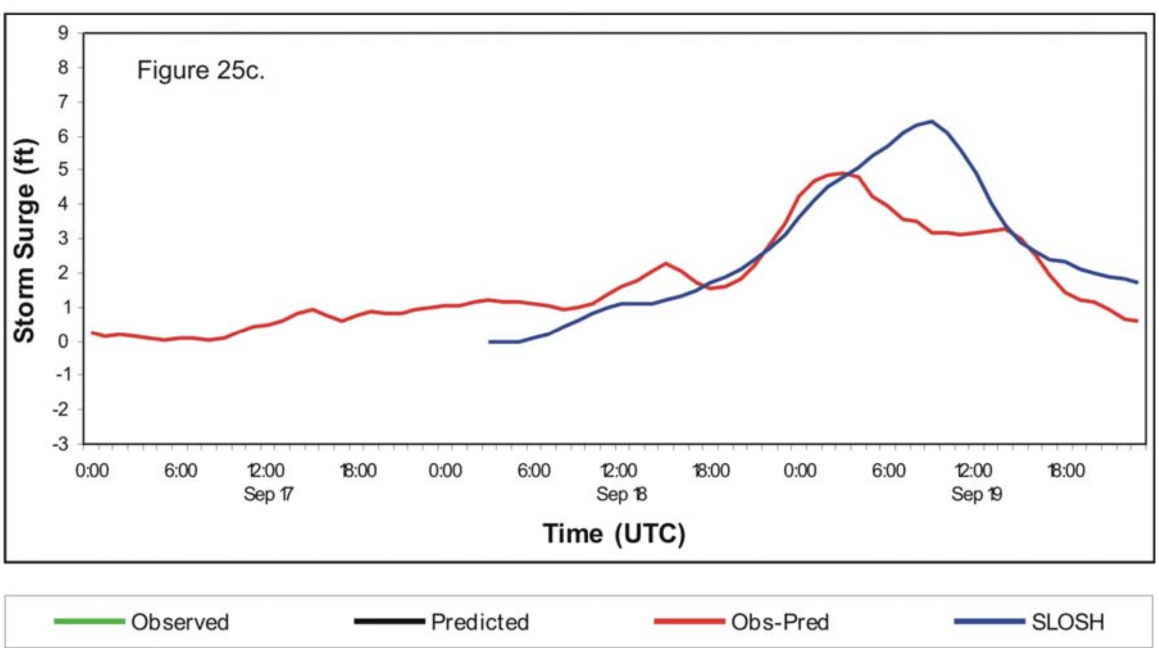


Observed Predicted Obs-Pred SLOSH

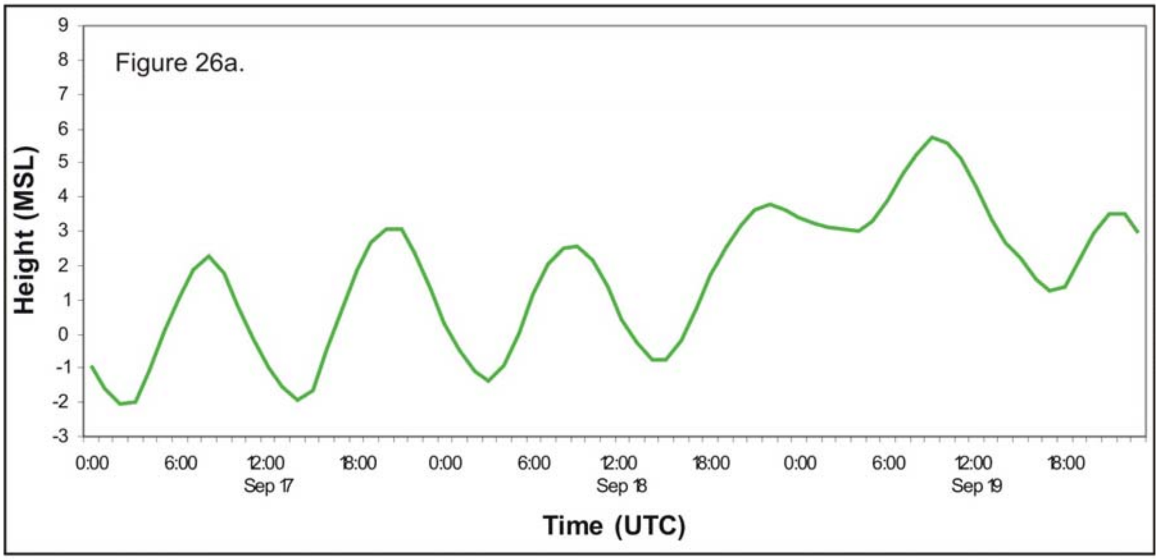
Ship John Shoal, NJ

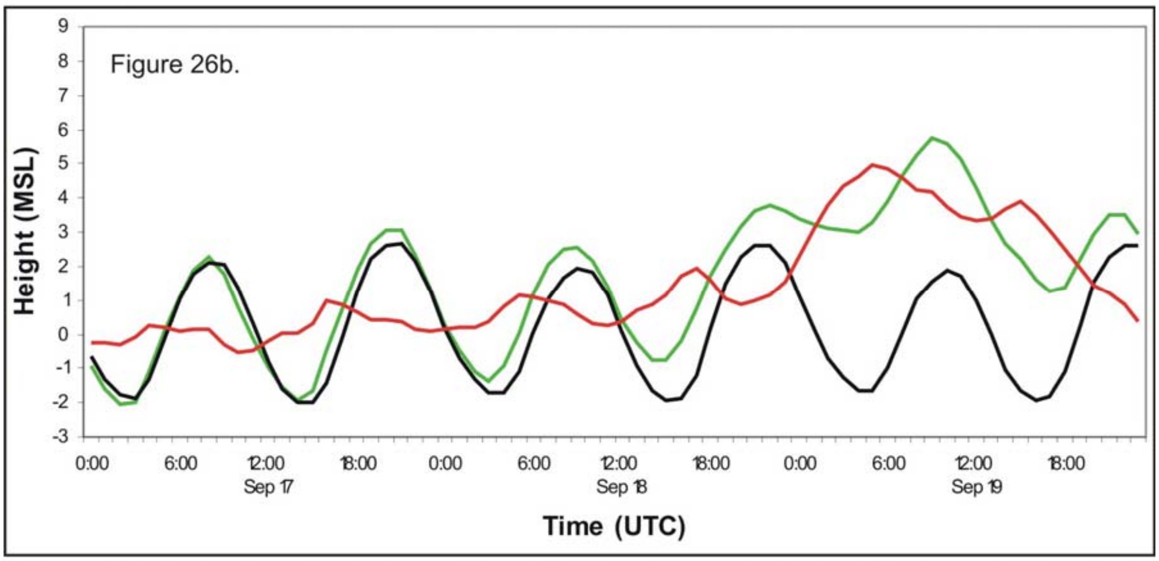


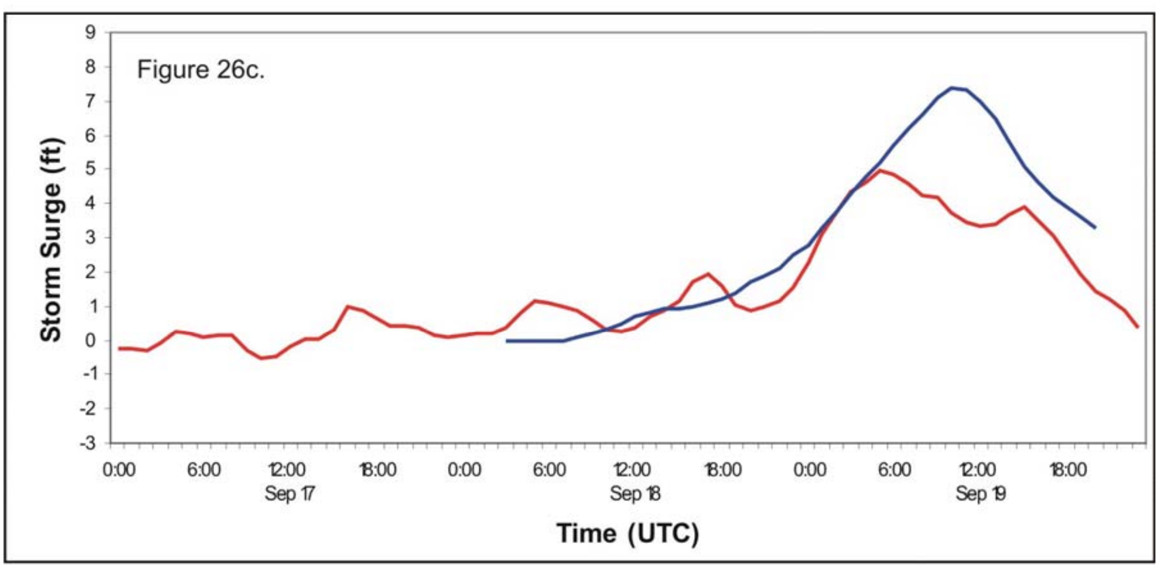




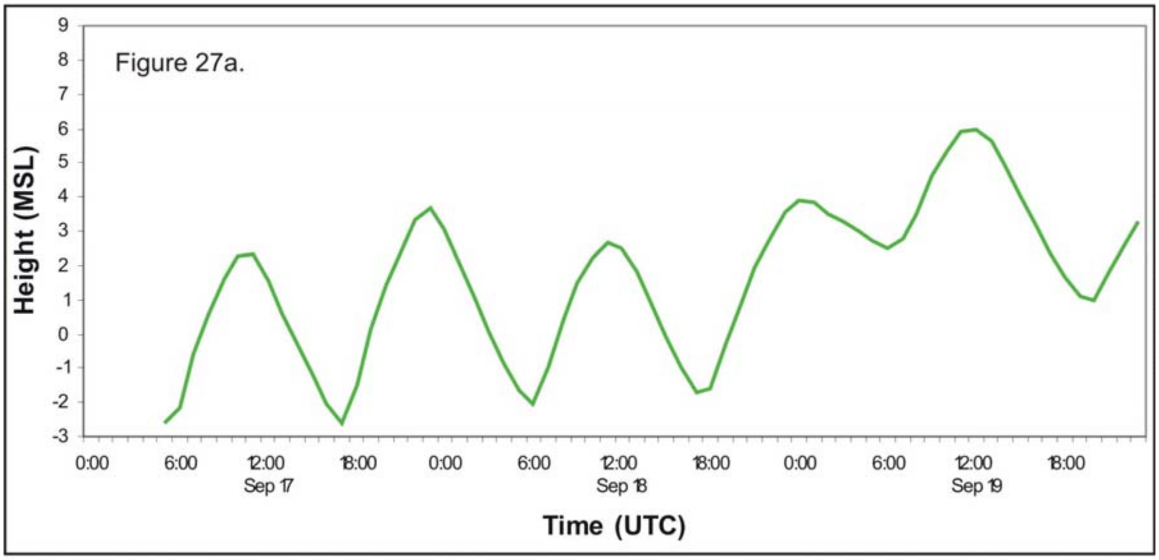
Reedy Point, DE

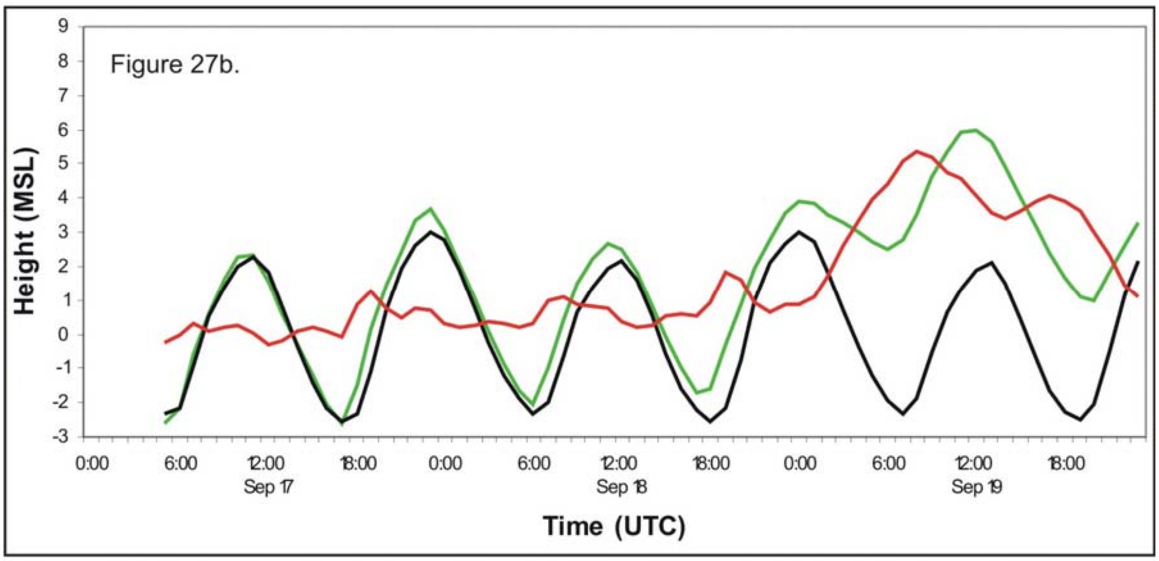


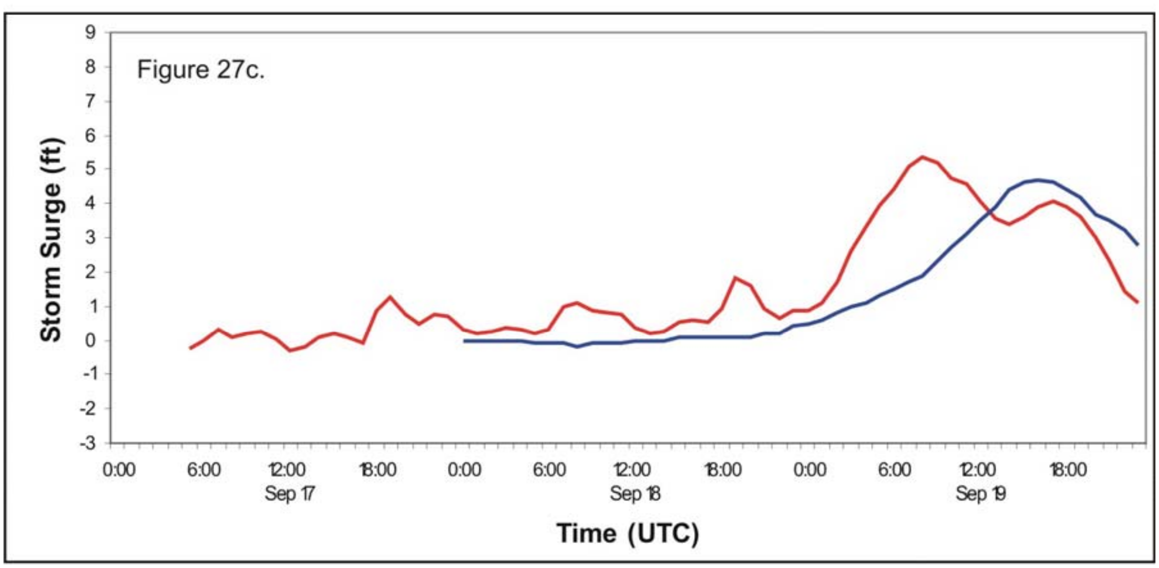




Philadelphia, PA







Observed
Predicted
Obs-Pred
SLOSH

APPENDIX B

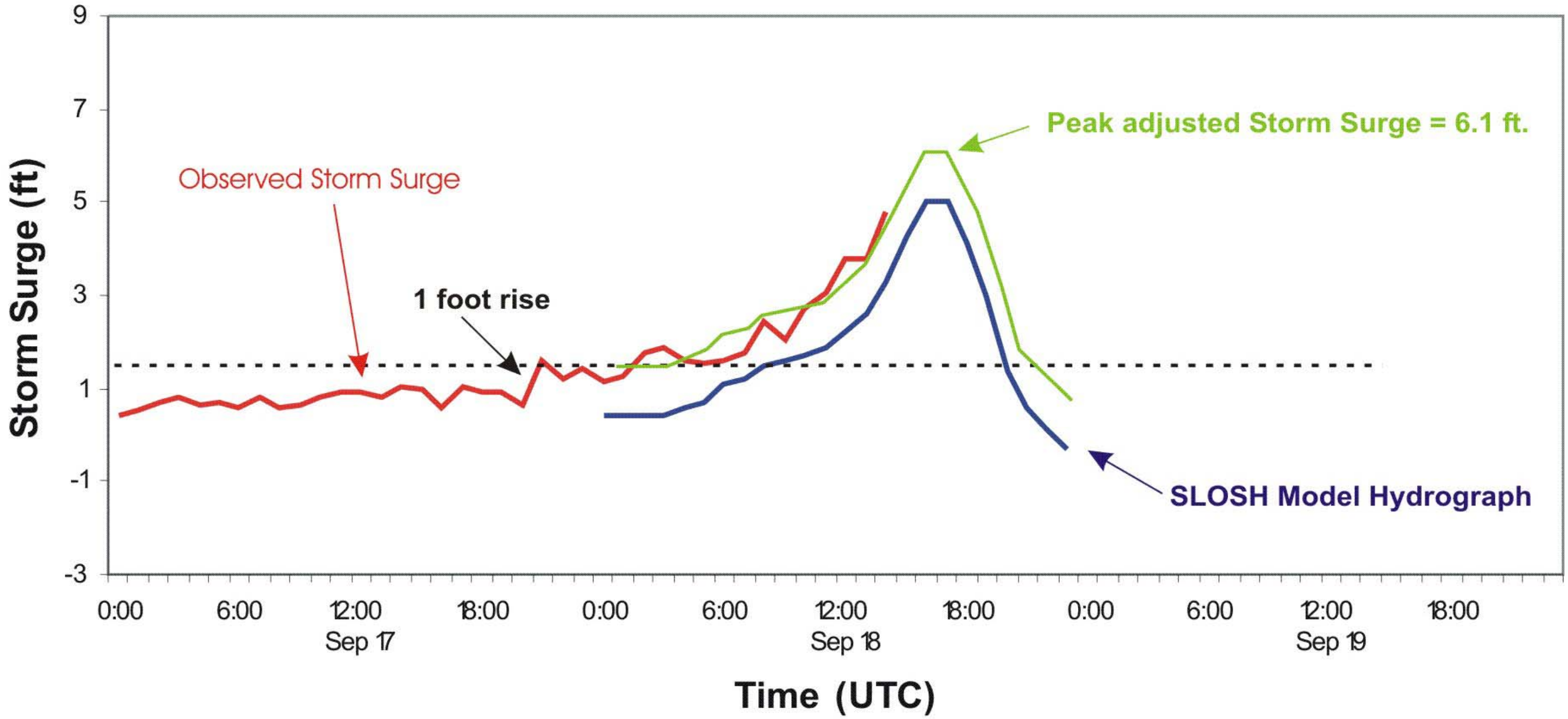


Figure 1. Cape Hatteras Fishing Pier Adjusted Storm Surge Hydrograph

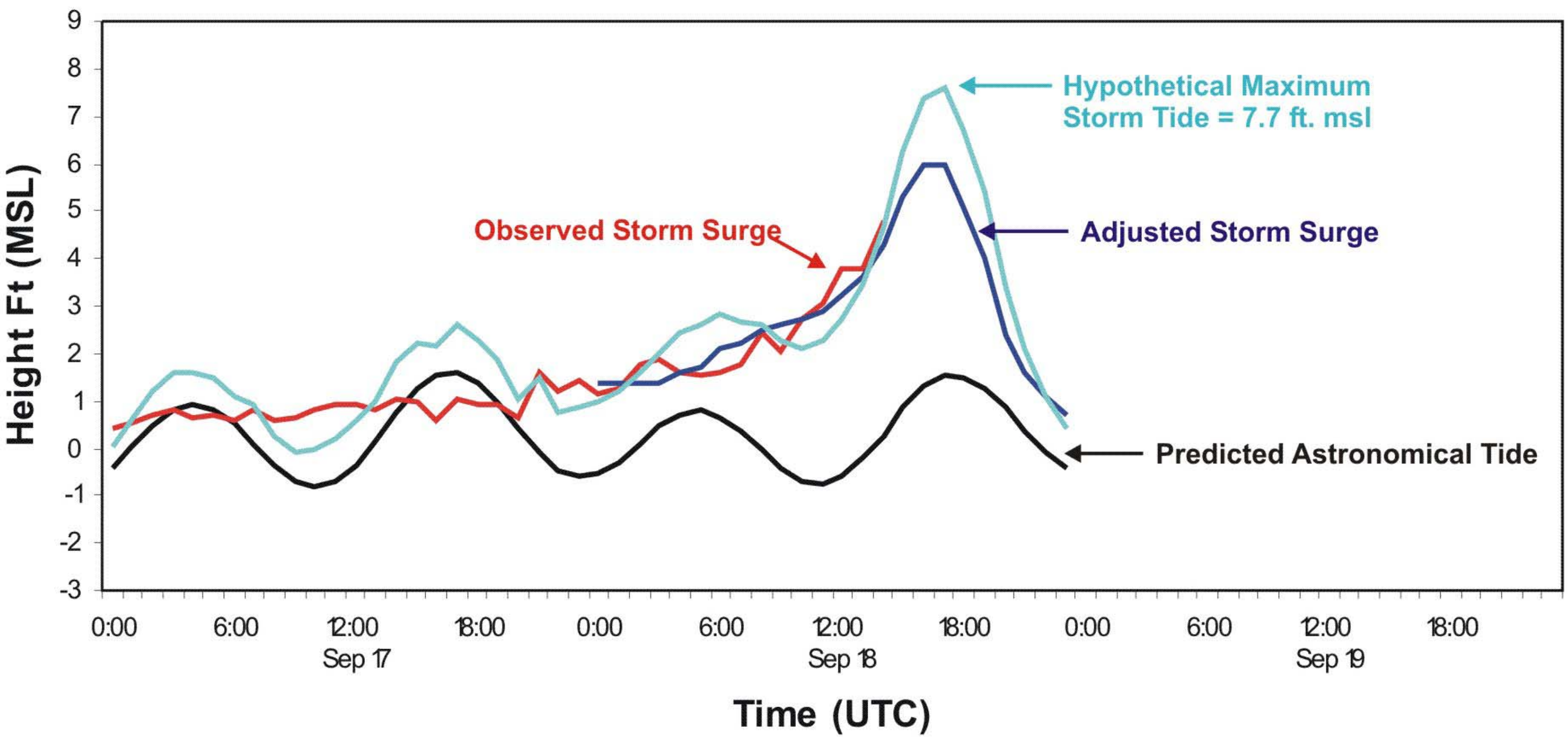


Figure 2. Cape Hatteras Fishing Pier Hypothetical Hydrograph

Appendix C

Hurricane Isabel Response Questionnaire
And
Statistical Reliability

Hurricane Isabel
Response Questionnaire

Hello, my name is _____________ and I'm calling on behalf of the Army Corps of Engineers and the **(NORTH CAROLINA DEPARTMENT OF PUBLIC SAFETY/ VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT/ MARYLAND EMERGENCY MANAGEMENT AGENCY)**. I'm conducting a telephone survey of residents concerning experiences in hurricane Isabel last year, so that we can improve hurricane evacuation plans for the future. May I please speak with the **(ROTATE):**

1. Youngest male over 18
2. Oldest male
3. Youngest female over 18
4. Oldest female in your household?

My questions will only take a few minutes. Your responses are important to us so that we may have accurate information about hurricane preparedness. Before we begin, let me assure you everything you say will remain strictly confidential.

To refresh your memory, Isabel was the hurricane that made landfall near Drum Inlet on the southern part of North Carolina's Outer Banks on September 18th of last year. At one time Isabel was an extremely powerful storm, but weakened before crossing the coast. A Hurricane Warning was issued from Cape Fear, North Carolina to Chicoteague, Virginia, and a Hurricane Watch was posted as far north as Sandy Hook, New Jersey.

1. Were you at home, that is, not out of town, when **HURRICANE ISABEL** began to threaten this area last year?
   _1_ Yes **(GO TO Q2)**
   _2_ No **(THANK AND TERMINATE)**
   _3_ Other **(THANK AND TERMINATE)**

   IF "NO," TERMINATE THE INTERVIEW BY RESPONDING "THANK YOU FOR YOUR TIME, BUT WE ARE LOOKING FOR PEOPLE WHO WERE IN THIS AREA AT THAT TIME. THANK YOU AGAIN. GOODBYE."

2. Did you leave your home to go someplace safer in response to the threat created by Hurricane Isabel?

_1_ Yes **(GO TO Q7)**
_2_ No **(GO TO Q3)**
_9_ Don't know **(THANK AND TERMINATE)**

3. What made you decide *not* to go anyplace else?

(CATEGORIZE - PROBE UP TO 3) (THEN GO TO Q4)

1. __ Forecast said storm would hit a different location
2. __ Officials seemed unsure whether evacuation was necessary
3. __ Heard conflicting messages from officials whether evacuation was necessary
4. __ Storm wasn't severe enough to pose a severe danger even if it hit
5. __ Location was on the weak (left) side of the storm
6. __ House is well built (strong enough to be safe in storm)
7. __ Home is elevated above the level of storm surge
8. __ Officials said evacuation was not necessary
9. __ Officials didn't say to evacuate
10. __ Media said evacuation wasn't necessary
11. __ Friend/relative said evacuation wasn't necessary
12. __ Probabilities indicated low chance of a hit
13. __ Other information indicated storm wouldn't hit
14. __ Had no place to go
15. __ Wanted to protect property from looters
16. __ Wanted to protect property from storm
17. __ Left unnecessarily in past storms
18. __ Job required staying
19. __ Waited too long to leave
20. __ Evacuation notice from officials came too late
21. __ Traffic too bad
22. __ Tried to leave, but returned home because of traffic
23. __ Too dangerous to evacuate because might get caught on road in storm
24. __ No place to take pets/Shelter would not accept pets
25. __ Concerned about being able to re-enter community after evacuating
26. __ Unable to re-enter area after evacuating in past storms (e.g., Floyd)
27. __ Had no transportation
28. __ Other, specify: ____
29. __ Don't know
30. No second or third option.

4. **IF** Isabel had looked to you like it was going to hit your location directly, would you have left your home to go someplace safer?

__1__ Yes
__2__ No
__3__ Don't Know/Depends
__4__ Other (Specify)____

5. Were you ready, that is had you made the necessary preparations, to leave your home to go someplace safer if the threat had gotten worse?

__1__ Yes
__2__ No
__3__ Don't Know/Depends
__4__ Other (Specify)____

6. What would you have done if Isabel had turned toward your location and it looked like it was too late for you to evacuate out of your county? Would you have ridden the storm out in your own home, gone someplace nearby, gone to another town in your county, or would you have tried to evacuate out of your county anyhow?

__1__ Would have ridden the storm out at home
__2__ Would have gone someplace nearby
__3__ Would have gone to another town in own county
__4__ Would have tried to get out of county
__5__ Don't Know/Depends

__6__ Other
(Specify)____

IF ANSWERING Q6, SKIP TO Q22

7. Did you go to a public shelter, a friend or relative's house, a hotel, or somewhere else? **(DO NOT READ OTHER OPTIONS)**
__1__ Public shelter (or Red Cross shelter)
__2__ Church
__3__ Friend/relative
__4__ Hotel
__5__ Workplace
__6__ Other, specify: ______________________________
__9__ Don't know

8. Is that **(ANSWER FROM Q7)** located in your neighborhood or someplace else?
__1__ Neighborhood **(SKIP TO Q12)**
__2__ Somewhere else
__9__ Don't know

9. Is that **(ANSWER FROM Q7)** located in your county?
__1__ Yes **(SKIP to Q11)**
__2__ No
__9__ Don't know

10. Is that **(ANSWER FROM Q7)** located in **(North Carolina/Virginia/Maryland)** or out-of-state (specify state)?
__1__ North Carolina
__2__ Virginia
__3__ Maryland
__4__ Delaware
__5__ Pennsylvania
__6__ D.C. (Washington, D.C.)
__7__ Other____
__9__ Don't know

11. What city or town was that (specify)?
__________________________________ __9__ Don't know

12. What convinced you to leave your home to go someplace safer? **(CATEGORIZE - PROBE UP TO 3)**
1. __ Advice or order by elected officials
2. __ Advice or order by public safety officials
3. __ Advice from National Weather Service
4. __ Advice/order from police officer or fire fighter
5. __ Advice from the media
6. __ Advice from friend or relative
7. __ Information about the severity of the storm
8. __ Concerned storm would cause home to flood
9. __ Concerned strong winds would make house unsafe
10. __ Concerned flooding would cut off roads
11. __ Had no transportation
12. __ Concerned that storm might hit
13. __ Forecast indicated storm would hit

14. __ Forecast indicated storm could hit
15. __ Probability (odds) were high that the storm could hit
16. __ National Weather Service issued Hurricane Watch
17. __ National Weather Service issued Hurricane Warning
18. __ Experience in Floyd
19. __ Experience in other storms
20. __ Other, specify:_______________________________________
21. __ Don't know
22. No Second or third option.

13. I'm going to ask about when you left your home to go someplace safer, but to refresh your memory I'm going to remind you when certain events took place. First, the National Hurricane Center issued a Hurricane Watch for Isabel, extending from the South Carolina/North Carolina state line northward to Chincoteague, Virginia, shortly before noon (11 AM) on Tuesday, September 16th. Then late that night, at 11 PM on that same Tuesday, September 16th, the Hurricane Center changed the watch to a hurricane warning as far north as the North Carolina/Virginia line. Early Wednesday morning, 5 AM on the 17th, the Warning was extended north to the Virginia/Maryland state line. Isabel made landfall near Drum Inlet, North Carolina at 1 PM in the afternoon on Thursday, September 18th.

On what day did you leave your home to go someplace safer?
__1__ Monday, September 15thth or earlier
__2__ Tuesday, September 16th
__3__ Wednesday, September 17th
__4__ Thursday, September 18th
__5__ Other ______________________
__9__ Don't know

14. About what time on the **(REPEAT DATE)** did you leave? **(USE 1 HOUR INCREMENTS) (TAKE MIDPOINT) (99=DK)**
___________ Hour **(IF 99, SKIP TO Q. 16)**

15. Was that morning AM or PM? (**NOTE: 12 O'CLOCK NOON = 12 PM) (NOTE: 12 O'CLOCK MIDNIGHT = 12 AM ON THE "NEW" DAY)**
__1__ AM (morning / or midnight until noon)
__2__ PM (afternoon/evening or noon until midnight)

16. How many vehicles were available in your household that you could have used to evacuate?
_____ Number of vehicles **(IF 0, GO TO Q17; OTHERWISE GO TO Q18)**
(9 = DK) (IF 1 OR MORE IN Q16, SKIP TO Q18) (8 =NA) (RECORD "0" IF NO VEHICLES ARE AVAILABLE)

17. Did your household members leave in someone else's vehicle, did they use public transportation, or did you evacuate another way?
__1__ Other's vehicles **(GO TO Q20)**
__2__ Public transportation **(GO TO Q20)**
__3__ Other, specify: ______________________ **(GO TO Q20)**
__9__ Don't know **(GO TO Q20)**

18. How many vehicles did your household take in evacuating? **(9 = DK) (8 =NA) (RECORD "0" IF NO VEHICLES ARE AVAILABLE)**
_________ Number of vehicles

19. When you evacuated, did you take a motor home or pull a trailer, boat, or camper?
 1 Yes
 2 No
 3 Other, specify:____
 9 Don't know

20. Did anyone in your household need assistance from an agency in order to evacuate or require any sort of special care in a shelter?
 1 Yes
 2 No **(Skip to Q22)**
 3 Other, specify:____
 9 Don't know

21. Did they receive transportation assistance from an agency, special care in a shelter, or both?
 1 Transportation
 2 Shelter care
 3 Both
 4 Other, specify:____
 9 Don't know

22. During the threat, did you hear either directly or indirectly anyone in an official position - such as elected officials, emergency management officials, police, etc. - say that you and people in your location should evacuate to a safer place? That is, did state or local officials issue any kind of evacuation notice that applied to you that you were aware of at the time it was issued?
 1 Yes **(GO TO Q23)**
 2 No **(GO TO Q25)**
 9 Don't know **(GO TO Q25)**

23. Did officials recommend that you **should** evacuate or did they say it was mandatory that you **must** evacuate?
 1 Should
 2 Must
 9 Don't know

24. Did police or other authorities come into your neighborhood going door-to-door or with loudspeakers, telling people to evacuate?
 1 Yes
 2 No
 9 Don't know

25. Would you do anything differently in the same situation again? **(CATEGORIZE) (PROBE UP TO 3)**
1. __ Would evacuate
2. __ Wouldn't evacuate
3. __ Would leave earlier
4. __ Would wait later to leave
5. __ Would go further away
6. __ Wouldn't go as far away
7. __ Would go to public shelter
8. __ Wouldn't go to public shelter
9. __ Would use different route
10. __ No

11. __ Other, specify:____
12. __ Don't know
13. __ No second or third option.

26. We're interested in how you got most of your information about Isabel - where the storm was; when it was going to hit; how severe it was. I'm going to list a number of different ways you might have gotten information, and I'd like you to tell me whether you relied upon that source none at all (0), a little (1), a fair amount (2), or a great deal (3). **(READ & ROTATE)**

	None	Little	Fair Amount	Great Deal	
a	0	1	2	3	Local radio stations
b	0	1	2	3	Local television stations
c	0	1	2	3	CNN on cable
d	0	1	2	3	The Weather Channel on cable
e	0	1	2	3	Other cable stations
f	0	1	2	3	The Internet
g	0	1	2	3	Services like America Online
h	0	1	2	3	Word of mouth

27. In general would you say that public officials in your city or county gave you the kind of information about Isabel that was helpful in deciding whether to evacuate or would you say it was generally not helpful?
__1__ Generally helpful
__2__ Generally not helpful
__3__ Mixed; some of both
__4__ Don't Know; Don't Recall
__5__ Other (specify)____

28. Would you say that public officials in your city or county were definite in their messages about whether you should evacuate in Isabel? That is, did they appear to be certain about whether you needed to evacuate or did they seem uncertain?
__1__ Very certain
__2__ Fairly certain
__3__ Generally not certain
__4__ Depends on which official
__5__ Sometimes certain, sometimes not
__6__ Don't Know; Don't Recall
__7__ Other (specify)____

29. In general, not just in Isabel, but in hurricanes generally, how much confidence do you have in the ability of public officials in your city or county to decide whether you really need to evacuate or not when they issue evacuation orders? Do you have a great deal of confidence, a fair amount of confidence, not much confidence, or no confidence in their ability to decide whether you need to evacuate?
__1__ Great deal of confidence
__2__ Fair amount of confidence
__3__ Not much confidence
__4__ No confidence
__5__ Don't Know/Depends
__6__ Other (specify)____

30. Do you think that public officials in your city or county tend to call for evacuation more often than they should, less often than they should, or about as often as they should?
   __1__ More often
   __2__ Less often
   __3__ About as often as they should
   __4__ Don't Know/Depends
   __5__ Other (specify)____

31. Did you or anyone in your household have to go to work while the Isabel evacuation was going on?
   _1_ Yes (**GO TO Q32)**
   _2_ No (**SKIP TO Q33)**
   _9_ Don't Know (**SKIP TO Q33)**

32. How did that affect the way your household responded during the evacuation?
   _1_ Not at all
   _2_ Kept household from evacuating
   _3_ Kept part of household from evacuating
   _4_ Delayed at least part of household from evacuating
   _5_ Other,____
   9 Don't Know

33. At one point when the storm was still well out in the Atlantic Isabel's maximum sustained winds were over 155 MPH. That made it a strong category 4 hurricane on the Saffir-Simpson scale, nearly a category 5 —what meteorologists would call a **very** dangerous hurricane. A category 1 on the scale is the weakest hurricane and a category 5 is the strongest possible. If Isabel had made landfall near your location with sustained winds of 155 MPH and then passed directly over your home, do you believe that your home would have been flooded by storm surge, river flooding, or wave action severe enough to pose a threat to your safety if you stayed in your home?
   _1_ Yes
   _2_ No
   _3_ Don't Know/Depends

34. Considering both wind and water, do you think it would have been safe for you to have stayed in your home if Isabel had hit near your location with winds of 155 MPH and then passed directly over your home?
   _1_ Yes
   _2_ No
   _3_ Don't Know/Depends

35. Later Isabel lost some strength and had winds of 125 MPH. That made it a category 3 hurricane on the Saffir-Simpson scale, still what meteorologists call a major hurricane. Eventually Isabel go weaker than this, but if Isabel had made landfall near your location with sustained winds of 125 MPH and then passed directly over your home, do you believe that your home would have been subject to storm surge, river flooding, or wave action severe enough to pose a threat to your safety if you stayed in your home?
   _1_ Yes
   _2_ No
   _3_ Don't Know/Depends

36. Considering both wind and water, do you think it would have been safe for you to have stayed in your home if Isabel had hit near your location with sustained winds of 125 MPH and then passed directly over your home?
 1 Yes
 2 No
 3 Don't Know/Depends

37. Before landfall Isabel lost more strength and had winds near 100 MPH when it crossed the coastline. That made it a category 2 hurricane on the Saffir-Simpson scale. If Isabel had made landfall near your location with sustained winds of 100 MPH and then passed directly over your home, do you believe that your home would have been subject to flooding or wave action severe enough to pose a threat to your safety if you stayed in your home?
 1 Yes
 2 No
 3 Don't Know/Depends

38. Considering both wind and water, do you think it would have been safe for you to have stayed in your home if Isabel had hit near your location with sustained winds of 100 MPH and then passed directly over your home?
 1 Yes
 2 No
 3 Don't Know/Depends
 4

39. How did you come to believe that your home would be safe or unsafe in hurricanes?
(CATEGORIZE) (PROBE UP TO 3)
1. _ Personal experience with this structure in past storms (e.g., Floyd, Hazel)
2. __ Personal experience in other structures in past storms this location
3. __ Personal experience in other storms in other locations
4. __ Observations of effects of storms on other structures in this location
5. __ Observations of effects of storms on other structures in other locations
6. __ Knowledge of how well this structure is built
7. __ Knowledge about safety of location of this structure
8. __ Height of location in the building
9. _ Information provided by the media about storm effects and construction
10. __ Information provided by the builder
11. __ Information provided by neighbors or long-time residents
12. __ Information provided by public officials
13. __ Don’t Know/Depends
14. __ Other (Specify)____
15. No second or third option.

40. While you were deciding whether to leave, did you have any concerns that you might try to evacuate but have the storm arrive while you were caught on the road because of heavy traffic?
 1 No
 2 Yes
 3 Don’t Know/Depends
 4 Other (Specify)____

41. About how many hours do you think it would take to evacuate everyone to safe locations if people in

this area were ordered to evacuate for a major hurricane? **(READ)**

__1__ 6 hours
__2__ 12 hours
__3__ 18 hours
__4__ 24 hours
__5__ more than 24 hours
__6__ don't know/depends

42. While you were deciding whether to leave, did you have any concerns about being able to get back into your community and to your home when you wanted to return after the evacuation?

__1__ No
__2__ Yes
__3__ Don't Know/Depends
__4__ Other (Specify)____

43. Have you ever personally had difficulty being allowed to get back to your home after evacuating in past storms?

__1__ No
__2__ Yes
__3__ Don't Know/Depends
__4__ Other (Specify)____

44. Which of the following would you say was the single most important factor in your decision to evacuate or not in Isabel? (**READ THE FIRST FOUR)**

__1__ The forecast track
__2__ The forecast strength of the storm
__3__ Statements issued by officials
__4__ Statements issued by media
__5__ Other factors (Specify)____
__6__ Combination of factors (don't list as a response option, but record if stated)
__9__ Don't Know

VA, MD IF NO TO Q2, SKIP TO Q51.
VA, MD IF YES TO Q2, SKIP TO Q78.
NC GO TO Q45

45. We're interested in how much confidence you have in the accuracy of hurricane forecasts made by the National Hurricane Center. The way we're going to do this is by describing three different aspects of a forecast and ask you how close you believe the Hurricane Center comes, on average, to getting each of them right, when the forecast is made 24 hours in advance. Obviously they do better with some storms than others, but we're interested in how well they do on average when you take their forecasts for all storms into account.

First of all, how well do you think the Hurricane Center does in forecasting how CLOSE the hurricane is going to come to a predicted location – that is, forecasting the track the storm will take. When the Hurricane Center is forecasting how close the storm will come to a certain location 24 hours from now, how far off do you think they are, on average? Would you say the average error is

__1__ 10 miles
__2__ 50 miles
__3__ 100 miles
__4__ 200 miles

__5__ more than 200 miles
__6__ Don't Know/Depends

46. Now we're interested in how well you believe the Hurricane Center does in forecasting WHEN the storm will arrive at the location they're predicting it will be in 24 hours. If they're predicting the storm will arrive at a certain location in 24 hours, on average how far off do you think they are with their forecasts? Would you say the average error is

__1__ half-an-hour
__2__ 1 hour
__3__ 3 hours
__4__ 6 hours
__5__ 12 hours
__6__ 18 hours
__7__ more than 18 hours
__8__ Don't Know/Depends

47. Do you think the storm is more likely to arrive sooner than predicted, later than predicted, or neither – that is, it's just as likely to arrive sooner as later.

__1__ Sooner
__2__ Later
__3__ Neither
__4__ Don't Know/Depends

48. Finally, we're interested in how well you believe the Hurricane Center does in forecasting how STRONG the storm will be 24 hours from the time they make the prediction. If they're predicting that in 24 hours the storm will have winds of 115 MPH, for example, on average, how far off do you think they are with their forecasts? Would you say the average error is

__1__ 2 MPH
__2__ 5 MPH
__3__ 10 MPH
__4__ 20 MPH
__5__ 50 MPH
__6__ more than 50 MPH
__7__ Don't Know/Depends

49. Do you think the storm is more likely to be stronger than predicted, weaker than predicted, or neither – that is, it's just as likely to be stronger as weaker.

__1__ Sooner
__2__ Later
__3__ Neither
__4__ Don't Know/Depends

50. How well do you think the National Hurricane Center does in forecasting hurricanes, compared to your favorite weather forecaster you watch on television? Would you say the Hurricane Center usually does better than the television forecaster, usually not as well, or usually about the same?

__1__ Better
__2__ Worse
__3__ Same
__4__ Don't Know/Depends

NC SKIP TO Q. 78 (I.E., IF ANSWERING Q58, SKIP TO Q78)

I would like for you to consider a possible situation that might exist in the future. With that in mind, please tell me what you would do in the following situations:

51. Suppose there's a **category 1** hurricane approaching from southeast of here. That's a category 1 storm on the Saffir-Simpson scale that goes up to 5. The storm has **winds of 80 MPH**, and there's a hurricane WARNING in effect for your community and all of the **(VIRGINIA/MARYLAND)** coast. Officials have called for evacuation of all areas that would be flooded by a category 1 hurricane and also for all mobile homes. In that situation, do you think you would leave your home to go someplace safer?
   _____ Yes
   _____ No **(SKIP TO Q58)**
   _____ Depends/Don't Know
   _____ Other (specify)______________________________

52. If you did evacuate, would you go to a public shelter, the home of a friend or relative, a hotel, or someplace else?
   _____ Public shelter
   _____ Friend or Relative
   _____ Hotel/Motel
   _____ Other Place (specify)_________________________
   _____ Depends/Don't Know

53. Would that be located in your own neighborhood, or someplace else?
   _____ Neighborhood **(SKIP TO Q57)**
   _____ Somewhere Else
   _____ Don't Know **(SKIP TO Q57)**

54. In what city would that be located? **(If they cannot name a specific city, WRITE "NOT SURE")**
   ____

55. Is that **(ANSWER FROM Q52)** located in your county?
   _____ Yes **(SKIP TO Q57)**
   _____ No
   _____ Don't Know

56. In what state is that located?
   _____ Virginia
   _____ Maryland
   _____ Delaware
   _____ D.C.
   _____ Pennsylvania
   _____ Other (specify)______________________________
   _____ Don't Know

57. What main highway (s) would you use when you evacuated? **(DO NOT READ, ACCEPT UP TO 3)**
   ____
   ____
   ____

_____ Don't Know

58. Now suppose there's a strong **category 2** hurricane approaching from southeast of here; that's a category 2 storm on the 5-point Saffir-Simpson scale. The storm has **winds of 100 MPH**, and there's a hurricane WARNING in effect for all your community and all of the **(VIRGINIA/MARYLAND)** coast. Officials have called for the evacuation of all areas that would be flooded by a category 2 hurricane and also all mobile homes. In that situation, do you think you would leave your home to go someplace safer?

_____ Yes
_____ No **(SKIP TO Q65)**
_____ Depends/Don't Know
_____ Other (specify)________________________________

59. If you did evacuate, would you go to a public shelter, the home of a friend or relative, a hotel, or someplace else?

_____ Public shelter
_____ Friend or Relative
_____ Hotel/Motel
_____ Other Place (specify)___________________________
_____ Depends/Don't Know

60. Would that be located in your own neighborhood, or someplace else?

_____ Neighborhood **(SKIP TO Q64)**
_____ Somewhere Else
_____ Don't Know **(SKIP TO Q64)**

61. In what city would that be located? **(If they cannot name a specific city, WRITE "NOT SURE")**

____

62. Is that **(ANSWER FROM Q59)** located in your county?

_____ Yes **(SKIP TO Q64)**
_____ No
_____ Don't Know

63. In what state is that located?

_____ Virginia
_____ Maryland
_____ Delaware
_____ D.C.
_____ Pennsylvania
_____ Other (specify)________________________________
_____ Don't Know

64. What main highway (s) would you use when you evacuated? **(ACCEPT UP TO 3)**

____
____
____
_____ Don't Know

65. What if a **strong category 3** hurricane were approaching from southeast of here. That's a category 3 storm on the 5-point Saffir-Simpson scale. Meteorologists refer to a category 3 hurricane as a **major**

hurricane. The storm has **winds of 125 MPH**, and there's a hurricane WARNING in effect for your community and for all of the **(VIRGINIA/MARYLAND)** coast. Officials have called for the evacuation of all areas that would be flooded by a category 3 hurricane and also for all mobile homes. In that situation, do you think you would leave your home to go someplace safer?

_____ Yes
_____ No **(SKIP TO Q72)**
_____ Depends/Don't Know
_____ Other (specify)______________________________

66. If you did evacuate, would you go to a public shelter, the home of a friend or relative, a hotel, or someplace else?

_____ Public shelter
_____ Friend or Relative
_____ Hotel/Motel
_____ Other Place (specify)_________________________
_____ Depends/Don't Know

67. Would that be located in your own neighborhood, or someplace else?

_____ Neighborhood **(SKIP TO Q71)**
_____ Somewhere Else
_____ Don't Know **(SKIP TO Q71)**

68. In what city would that be located? **(If they cannot name a specific city, WRITE "NOT SURE")**

____

69. Is that **(ANSWER FROM Q66)** located in your county?

_____ Yes **(SKIP TO Q71)**
_____ No
_____ Don't Know

70. In what state is that located?

_____ Virginia
_____ Maryland
_____ Delaware
_____ D.C.
_____ Pennsylvania
_____ Other (specify)______________________________
_____ Don't Know

71. What main highway (s) would you use when you evacuated? **(ACCEPT UP TO 3)**

____
____
____
_____ Don't Know

72. Suppose public safety officials arranged for public shelter space to be provided for evacuees from your community in an inland location outside your city or county, but in a different location than you would normally prefer to evacuate to. Would you be likely to go to that location to take advantage of the shelter being provided?

_____ Yes

_____ No
_____ Don't Know/Depends
_____ Not Applicable – Wouldn't Evacuate
_____ Other (specify)____________________________

73. How many vehicles would be available in your household that you could use to evacuate?
_____ Number of vehicles **(IF 0, SKIP TO Q76; OTHERWISE GO TO Q74)**
(33 = DK) (RECORD "0" IF NO VEHICLES ARE AVAILABLE)

74. How many vehicles would your household take if you evacuated? **(33 = DK) (RECORD "0" IF NO VEHICLES WOULD BE TAKEN)**
_________ Number of vehicles

75. If you evacuated, would you take a motor home or pull a trailer, boat, or camper?
____ Yes
____ No
____ Other, (specify)____________________________
____ Don't know

76. In an evacuation would you or anyone in your household need assistance from an agency in order to evacuate or require any sort of special care in a shelter?
____ Yes
____ No **(SKIP TO Q78)**
____ Not sure **(SKIP TO Q78)**

77. Would the person need transportation assistance from an agency, special care in a shelter, or both?
____ Transportation only
____ Special need (disability or medical problem)
____ Both
____ Other, (specify)____________________________
____ Don't know

78. Have you identified the safest location in your home to ride out a strong hurricane if you had to?
__1__ Yes
__2__ No
__9__ Don't Know/Not Sure

79. Do you have any kind of window protection such as storm shutters, security film, or plywood sheets designed to protect the windows during a strong hurricane?
__1__ Yes **(GO TO Q80)**
__2__ No **(SKIP TO Q81)**
__9__ Don't Know/Not Sure **(SKIP TO Q81)**

80. What kind of protection is it?
__1__ Permanent roll-down metal panels
__2__ Removable metal panels
__3__ Plywood sheets
__4__ Security Film
__5__ Impact-resistant glass
__6__ Other____________________________
__9__ Don't Know/Not Sure

81. Do you believe window protection like that would mainly just prevent the windows from breaking and reduce the danger of flying glass, or do you believe they would also significantly reduce the total damage your house would suffer in other ways?

__1__ Mainly Windows
__2__ Total Damage Also
__9__ Don't Know/Not Sure

82. Other than window protection, what permanent improvements, if any, have you made to your home to reduce the damage to your property in a hurricane? **(CATEGORIZE) (PROBE UP TO 2)**

1. __Roof/truss Strengthening
2. __Door/Garage Door Protection
3. __Flood proofing
4. __Other (Specify)________________________
5. _ None
6. _Don't Know/Not Sure
7. No second option.

83. How much money do you plan to spend **this year** on changes to your home to make it stronger or safer from hurricanes? **(9999=DK)**
$________________________

84. Is your home or building elevated on pilings or fill material to raise it above flood water?
__1__ Yes
__2__ No
__9__ Don't Know/Not Sure

85. Was your home damaged in Isabel?
__1__ Yes
__2__ No **(SKIP TO Q87)**
__9__ Don't Know/Not Sure **(SKIP TO Q87)**

86. How much damage, in dollars, did you experience in Isabel?
__1__ None
__2__ Less than $1,000
__3__ $1,000 to $4,999
__4__ $5,000 to $9,999
__5__ $10,000 to $24,999
__6__ $25,000 to $49,999
__7__ $50,000 or more
__8__ Don't Know/Refused

87. What was the most damage, in dollars, you've ever experienced to your property as the result of ANY hurricane?
__1__ None
__2__ Less than $1,000
__3__ $1,000 to $4,999
__4__ $5,000 to $9,999
__5__ $10,000 to $24,999
__6__ $25,000 to $49,999
__7__ $50,000 or more
__8__ Don't Know/Refused

NOW WE HAVE JUST A FEW MORE QUESTIONS FOR BACKGROUND PURPOSES ONLY.

88. Which of the following types of structures do you live in? Do you live in a: **(READ)**
__1__ Detached single family home?
__2__ Duplex, triplex, quadruple home?
__3__ Multi-family building -- 4 stories or less? (Apartment/condo)
__4__ Multi-family building -- more than 4 stories (Apartment/condo)
__5__ Mobile home

6 Manufactured home
7 Some other type of structure
8 Don't Know
9 Refused

IF ANSWER IS NOT MOBILE HOME OR MANUFACTURED HOUSE, GO TO Q91

89. In what year did you buy your Mobile Home or Manufactured House? **(2222=Don't Know)**

____

90. Was it new when you bought it?
1 Yes
2 No
3 Don't Know

91. How old were you on your last birthday?
____ Number of years **(99 = DK)** (88=REFUSED)

92. How long have you lived in your present home? **(ROUND UP) (99 = DK)** (88=REFUSED)
____ Number of years

93. How long have you lived in the coastal area of **(NORTH CAROLINA/VIRGINIA/MARYLAND)**? **(ROUND UP) (99 = DK)**(88=REFUSED)
____ Number of years

94. How many people live in your household, including yourself? **(99 = DK)** (88=REFUSED)
____ Number of people **(IF 1, SKIP TO Q76)**

95. How many of these are children, 17 or younger? **(99 = DK)** (88=REFUSED)
____ Number of children

96. Do you own your home or rent?
1 Own
2 Rent
3 Other

97. Do you have any pets?
1 Yes
2 No
9 Refused

98. Which race or ethnic background best describes you? **(READ)**
1 African American or Black
2 White or Caucasian
3 Hispanic
4 Asian
5 American Indian
6 Other
9 Refused

99. Which of the following ranges best describes your total household income for 2003? **(READ)**
1 Less than $15,000

2 $15,000 to $24,999
3 $25,000 to $39,999
4 $40,000 to $79,999
5 Over $80,000
9 Refused

100. Which category best describes your education level? **(READ)**
1 Some high school
2 High school graduate
3 Some college
4 College graduate
5 Post graduate
9 Refused

VA, MD SKIP TO END
NC, GO TO Q 101

101. Were you living at your current address when Hurricane Floyd threatened this area in 1999?
1 Yes
2 No **(SKIP TO Q103)**
9 Don't Know/Don't Remember **(SKIP TO Q103)**

102. Did you leave your home to go someplace safer in Floyd?
1 Yes
2 No
9 Don't Know/Don't Remember/Not Applicable

103. Were you living at your current address when Hurricane Bonnie threatened this area in 1998?
1 Yes
2 No **(SKIP TO Q105)**
9 Don't Know/Don't Remember **(SKIP TO Q105)**

104. Did you leave your home to go someplace safer in Bonnie?
1 Yes
2 No
9 Don't Know/Don't Remember/Not Applicable

105. Were you living at your current address when Hurricane Felix threatened this area in 1995?
1 Yes
2 No **(SKIP TO Q107)**
9 Don't Know/Don't Remember **(SKIP TO Q107)**

106. Did you leave your home to go someplace safer in Felix?
1 Yes
2 No
9 Don't Know/Don't Remember/Not Applicable

107. Were you living at your current address when Hurricane Emily threatened this area in 1993?
1 Yes
2 No **(SKIP TO END)**
9 Don't Know/Don't Remember **(SKIP TO END)**

108. Did you leave your home to go someplace safer in Emily?
1 Yes

__2__ No
__9__ Don't Know/Don't Remember/Not Applicable

Thank you so much. Sometimes my supervisor will call people to check on my work. May I get your first name in case she wants to check?

rname.

RECORD INTERVIEW INFORMATION ON RESPONDENT DISPOSITION SHEET

vgender. Sex of respondent __1__ Male __2__ Female
iname. Interviewer ID
vdate. Date of survey
vtele. Phone number
vstate. 1= MD
2= VA
3= NC
vzone. 1= cat 1 zone
2= cat 2-4 zone
3= non-surge zone
vcluster.
1= MD South
2= MD DC
3= MD Annapolis
4= MD Baltimore
5= MD E Shore
6= NC Outer Banks north
7= NC Outer Banks south
8= NC Sound
9= VA 1
10=VA 2
11= VA 3
12=VA 4

Zip Code???

Statistical Reliability

Figures reported from surveys cited in this report are based upon samples taken from larger populations. The sample values provide estimates of the values of the larger populations from which the samples were selected, but usually are not precisely the same as the true population values. In general, the larger the number of people in the sample, the closer the sample value will be to the true population value. A sample of 200 will provide estimates which one can be 90% “confident” are within 4 to 6 percentage points of the true population values, whereas a sample of 100 will provide the same degree of confidence of being within 5 to 8 percentage points of the true population values. With a sample of 50, one can be 90% "confident" of being within 7 to 11 percentage points of the actual population value, and a sample of 25 is 90% "accurate" only within 10 to 17 percentage points. With a sample of 50, one can be 90% "confident" of being within 7 to 12 percentage points of the actual population value. A sample of 25 is 90% "accurate" only within 10 to 17 percentage points.

The ranges (e.g., "10 to 17") stem from the fact that the reliability of an estimate depends not only on the size of the sample but also upon how much agreement there is among the responses. Having 90% of the respondents give a particular answer means almost everyone agreed. By the same reasoning, if only 10% gave a particular response, almost everyone agreed (i.e., 90% disagreed with the 10% but agreed with one another). The maximum disagreement is for the responses to be split 50-50. Thus, if 90% (or 10%) of a sample of 100 give a particular response, that estimate will be within 5 percentage points of the true population value 90% of the time. If 75% (or 25%) of a sample of 100 give a particular response, that estimate will be within 7 percentage points 90% of the time. If 50% of a sample of 100 give a particular response, that estimate will be within 8 percentage points 90% of the time.

Therefore, readers should keep in mind that some estimates provided in this report are more statistically reliable than others. This is particularly noteworthy in drawing conclusions about whether two survey results are "different" from one another. Differences of a few percentage points in sample results of 100 or less do not necessarily mean the populations from which the samples were drawn are different. When the aggregate samples are broken down into subgroups, the reliability of estimates for the subgroups suffers. Tables contain actual sample sizes used to calculate the values reported in the table. Sample sizes vary from table to table because not all questions were asked of all respondents (people who didn’t evacuate weren’t asked where they went, for example), some respondents refused to answer some questions, and in a few cases responses were invalid.

Appendix D

National Hurricane Mitigation and Preparedness Program Strategic Plan

NATIONAL HURRICANE MITIGATION AND PREPAREDNESS PROGRAM

Developed By The

Interagency Coordinating Committee On Hurricanes (ICCOH)

Federal Emergency Management Agency
Lead Agency

PROGRAM OVERVIEW

Historically, hurricanes have caused more loss of life and a greater amount of property damage than all other natural or manmade disasters. Six of the top ten worst disasters as ranked by the Federal Emergency Management Agency (FEMA) disaster relief costs were caused by tropical weather systems. Despite this persistent and known threat, 3,600 people a day move to our nation's coastal counties. Currently more than 144 million people live in hurricane prone areas. A hurricane that makes landfall in a major coastal city has the potential to cause significant loss of life and damage to property. Every year, severe weather events create economic losses averaging $42 billion, and hurricanes and tropical systems are a major contributor to this national problem.

The Interagency Coordinating Committee on Hurricanes (ICCOH) is an ad-hoc committee comprised of Federal agencies that have programmatic responsibilities to address Tropical Cyclones and other severe weather hazards. FEMA as chair of the ICCOH acts as the lead coordinating agency to accomplish the goals and objectives in this plan. Under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act as amended, the National Hurricane Mitigation and Preparedness Program (NHMPP) is a national partnership between Federal, State and local governments and other organizations that provides vital preparedness, response, and mitigation services to State and local governments and hurricane threatened populations.

The NHMPP (formerly the National Hurricane Program) covers 22 states and U.S. Territories and is a cooperative effort aimed at reducing the risk to lives and property from all hazards associated with hurricanes. The Program provides coastal states and inland communities with technical guidance, technical assistance, decision assistance tools, and financial support to carry out activities that reduce the hurricane risk by minimizing the loss of life and mitigating damage to property.

MISSION STATEMENT

"To lead the planning, preparedness, and mitigation activities to create an informed citizenry ready to react to hurricane and tropical system threats."

VISION STATEMENT

"A Nation prepared- protecting human life and property from the hazards of hurricanes and tropical systems."

STRENGTHS AND CORE PRACTICES; Strategic Partnerships

The NHMPP will continue to be a dynamic program continuously adapting to customer needs. Continued success requires more emphasis placed on building additional strategic partnerships, improving and developing innovative products, providing competent, reliable services and timely, accurate education and training programs.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) is an integral partner in the National Hurricane Mitigation and Preparedness Program. The Corps has traditionally contributed approximately $1 million annually to the NHMPP. Technical support is provided through USACE management of the Comprehensive Hurricane Preparedness Studies (CHPS), Post Storm Studies and Geographic Information Systems (GIS)/Mapping services. The USACE supports the development, improvement, and success of the HURREVAC model. The USACE is currently conducting wave research to better identify hazards associated with coastal areas.

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) actively supports the NHMPP through its subordinate agencies such as the National Weather Service (NWS), the River Forecast Centers (RFCs), Tropical Prediction Center/National Hurricane Center (TPC/NHC) and Coastal Services Center (CSC). These agencies provide funding, research, training, mapping, real-time forecast and technical support to assist with hurricane preparedness and response issues. TPC/NHC also houses FEMA's Hurricane Liaison Team that serves as a link between the NHC and the emergency management community during times of hurricane threat to the U.S. and territories.

NOAA's office of the Federal Coordinator for Meteorology (OFCM) coordinates, on a Federal interagency basis, the Nation's hurricane forecast and warning program, conducts the annual Interdepartmental Hurricane Conference and publishes the National Hurricane Operations Plan annually.

US Department of Transportation

The U.S. Department of Transportation (USDOT) provides technical assistance for various FEMA evacuation planning efforts and response teams through the Federal Highway Administration (FHWA). FHWA is the lead of the Evacuation Liaison Program and financially supports the Evacuation Traffic Information System (ETIS), which provides the transportation and the emergency management community the means to monitor traffic congestion during evacuation events. Technical support is also provided in the form of training and education of ETIS at the Federal and State level.

State and Local Emergency Management, Departments of Transportation and Law Enforcement Agencies

State and Local Agencies offer direction of program initiatives and identify problem areas. These partners are an integral part of planning and managing hurricane evacuation processes, and are relied upon to provide coordination and input into program efforts and activities.

National Emergency Management Association

The National Emergency Management Association (NEMA) is an advocate for state and local emergency management issues and programs. NEMA aids the NHMPP with staying abreast of new issues related to hurricanes and tropical storms, and assist with promoting effective planning, mitigation and preparedness.

Private Sector

The NHMPP coordinates with partners within the private sector for project development, research, and public awareness. Private sector organizations, such as the American Red Cross and universities, help to ensure the NHMPP produces quality educational tools, decision assistance modeling, studies, post storm assessments and technical data reports and assists in the communication and delivery of these products to the public.

STRENGTHS AND CORE PRACTICES; Strategic Products

Hurricane Evacuation Studies (HES)

Developed by the NHMPP and the USACE, Hurricane Evacuation Studies (HES) have long been used by local decision-making officials as a risk and vulnerability assessment tool to aid them in hurricane planning and response efforts. HES includes transportation/road network analysis and behavioral response data in conjunction with risk and vulnerability assessments for local communities, and produces evacuation clearance time data for local and regional areas. The HES is composed of six components and produces a wealth of data in the following categories:

1. Hazard Analysis
2. Vulnerability Analysis
3. Shelter Analysis
4. Behavioral Analysis
5. Transportation Analysis
6. Decision Timing Analysis

Comprehensive Hurricane Study Products

To effectively address the needs expressed by state and local partners, the NHMPP is developing a modernized study process that will produce comprehensive hurricane products and services. This process will result in tailored studies for state and local jurisdictions that will address traditional HES analysis, as well as, other hurricane hazard issues that have not previously been addressed. Future study items could include:

1. Re-entry
2. Business Mitigation & Recovery
3. Community Storm Impact
4. Recovery Issues
5. Communication Process
6. Disaster Mitigation

HURREVAC

The HURREVAC software is a tropical cyclone tracking and decision assistance tool available for government entities. This real-time data analysis tool allows state and local emergency management officials to make prudent and informed decisions based on information developed in the HES/CHPS and data distributed by the NWS and the TPC/NHC.

Storm Surge Mapping

A major planning product that is produced by the HES/CHPS is storm surge mapping. Local Emergency Managers utilize storm surge mapping to aid in determining hurricane evacuation zones showing populations vulnerable to these life-threatening hazards. Storm Surge maps are created in a digital form and can be imported into all hazard data portals, publications, and programs. Storm Surge maps are based upon NOAA SLOSH model data.

Post Storm Assessments

Post Storm Assessments are conducted after significant hurricanes make landfall. Post Storm Assessments have been conducted by since 1985, and serve as an avenue for the hurricane community to verify product results and data provided to emergency management. Some examples include assessments from Hurricanes Hugo, Andrew, Opal, Georges, Brett, Floyd and Lili.

HAZUS

Hazards United States (HAZUS) is a FEMA sponsored damage and loss estimation tool designed to support Federal, State and local mitigation, preparedness, response and recovery initiatives associated with earthquakes, floods, and tropical cyclones. HAZUS allows communities to better prepare for disasters by evaluating various scenarios.

Building Performance Assessment Team Reports.

The Building Performance Assessment Team (BPAT) Program is an award-winning program uses the combined resources from a Federal, State, Local, and Private-Sector Partnership to study building performance as part of FEMA's national mitigation effort. These teams of experts study building performance in response to major natural. The first widely publicized BPAT Report was for Hurricane Andrew and was completed by Mitigation Division.

Evacuation Traffic Information System (ETIS)

ETIS is a real-time hurricane evacuation traffic-forecasting tool, used to aid FEMA and

State Emergency Management and Departments of Transportation with evacuation coordination and communication.

STRENGTHS AND CORE PRACTICES; Strategic Services

Technical Support

The NHMPP partners provide expertise on a wide range of hurricane related hazard areas, research, techniques and strategies. Program partners also participate in various hurricane-planning meetings and conferences to educate the public about new program initiatives and program findings related to hurricane risk and threatened populations.

Financial Support

Through the NHMPP, FEMA currently provides $2.9 million annually in Emergency Management Program Grant funding to 22 states and U.S. Territories. Other NHMPP partners provide state and local jurisdictions with grant funding opportunities to address hurricane program related issues and needs.

Evacuation Liaison Team

The Evacuation Liaison Team (ELT) is made up of emergency management and transportation specialists that facilitate the coordination and sharing of information between state jurisdictions during multi-state hurricane evacuations. The U.S. Department of Transportation is the lead agency with support from FEMA. The ELT serves as an information clearinghouse and communication link between Federal and state emergency management, highway patrol and transportation officials. The ELT is primarily activated for storm events threatening the Gulf of Mexico and southeastern United States.

Hurricane Liaison Team

The Hurricane Liaison Team (HLT) is a cadre of Federal, State, and local emergency managers with hurricane preparedness experience. As tropical systems threaten the U.S., the HLT deploys to the National Hurricane Center to assist in the coordination efforts between the NHC and Federal, State and local emergency managers threatened by these systems. Team members provide immediate and critical storm information for use by decision makers so that all levels of government can make competent and informed decisions. The HLT concept originated from the active 1995-hurricane season where an unprecedented burden of timely information dissemination was placed on the National Hurricane Center.

Training, Education and Outreach

The NHMPP is constantly striving to educate hurricane risks populations and decision-making officials by producing cutting edge preparedness, awareness, educational publications, and decision assistance tools that address hurricane hazards and issues. Partnering agencies provide multiple training opportunities, various multi-media awareness publications for the emergency management community and the general population in order to support the program's vision of "A Nation Prepared- protecting human life and property from the hazards of hurricanes and tropical systems."

Science and Technology

Based on historical storm events, operational issues, and customer feedback the NHMPP is dedicated to identifying new research opportunities and needs to enhance products, services, and outreach.

PROGRAM CHALLENGES

The United States coastal population is grossly undereducated about the hazards of tropical systems and is becoming more complacent in many areas due to the lack of land-falling storms. In spite of the threat, unprecedented growth is continuing in coastal areas with more than one third of the U.S. population living within 50 miles of coastline.

Recent experiences with land falling tropical systems have shown that there are still major unmet needs with regard to the following:

- Inland flooding
- Storm surge mapping
- Evacuation zones and timetables
- Sheltering arrangements
- Traffic flow solutions
- Citizen complacency
- Public health and catastrophic recovery issues
- Re-entry planning
- Program turnover at all levels
- Predictive models (e.g. rainfall and inland flooding).

PROGRAM OPPORTUNITIES

Our rapidly expanding populations in the U.S. coastal regions demands that the NHMPP meet new challenges by embracing additional program partnerships. Expansion of partnerships for the program will allow the development of a variety of disciplines, which will bring in innovative ideas and proactive technological advances. Harnessing new technology will help the NHMPP to create new technical tools and improve existing products, methods, and techniques that will enhance state and local capability to effectively plan and respond to tropical cyclones and their effects. Partnering with other agencies to create real time information tools for government decision-making will improve a community's ability to respond. It is imperative that the program partners work together to maximize resources, obtain new funding, understand customer needs and avoid duplication of efforts.

CRITICAL SUCCESS FACTORS

National Leadership

Through strategic partnerships, the NHMPP will be the national resource of hurricane mitigation and preparedness information and expertise with the Federal Emergency Management Agency acting as the lead Federal agency.

Adequate Funding

Our Nation's vulnerability to hurricanes is rapidly increasing, making it difficult for the NHMPP to adequately address new issues and problems as they arise. The NHMPP must prioritize current and future program efforts, and maximize all available resources to ensure that issues, needs, and problems can be solved. New resources and funding must be obtained to meet the goals of the strategic plan.

Enhance Strategic Partnerships

Through enhanced partnerships, the NHMPP will secure needed expertise that will help to increase outreach efforts, improve programs initiatives, and improve the products provided to our customers.

State and Local Implementation

Ensuring the state and local partners are trained to use NHMPP products correctly to enhance planning techniques, decision-making, preparedness and communication. Major training initiatives, lead by the NHMPP, are required to make sure that decision makers at all levels fully understand the capability of products and tools to help them make better decisions as hurricanes threaten.

GOALS AND OBJECTIVES

Each year the ICCOH will develop supporting Fiscal Year Goal Action Plans that detail program efforts and initiatives.

LEADERSHIP

Goal #1: Awareness and coordination between Federal, state, and local governments is achieved, eliminating redundancy or gaps in hurricane preparedness and mitigation related activities.

Supporting Objectives

- Provide national leadership on hurricane preparedness, response and mitigation activities by Federal, state and local governments.
- Define partnership roles and responsibilities, enhance existing partnerships and establish new partnerships with other Federal and state agencies, organizations, non-governmental organizations and private industry to foster the mission and activities of the NHMPP.
- Facilitate and participate in meetings, conferences and workshops on hurricane hazard

issues to establish communication between Federal, state and local agencies and organizations.

PRODUCTS & SERVICES

Goal #2: An informed emergency management community and public that makes timely and effective decisions to reduce loss of life and minimize damage.

Supporting Objectives

- Provide state and local officials with the tools and services to aid decision-making.
- Establish ongoing dialog between the emergency management, transportation and law enforcement community, and the public in real time during tropical cyclone threats.
- Continuously evaluate NHMPP products, customer needs, issues, procedures and services for relevance and effectiveness in meeting the needs of Federal, state and local emergency managers to improve our products.
- Enhance hurricane value-added services, publications and tools in a useful form in order to promote better decision-making and awareness.
- Based on customer needs, facilitate value-added input into other Federal initiatives to enhance products and services addressing all hazards preparedness, response, recovery and mitigation activities.

SCIENCE & TECHNOLOGY

Goal #3: Facilitate the transition of scientific and technological advances into operations to enhance program products, services and operational response.

Supporting Objectives

- Based on storm events, evaluation, operational issues and customer feedback, identify new hurricane research needs and opportunities.
- Work with the research community to address new research needs and opportunities.
- Capitalize on existing technology and incorporate emerging science and technology to enhance products, services and outreach.
- Assess changing behavioral patterns associated with increased institutional and public knowledge of hurricanes.

TRAINING, EDUCATION & OUTREACH

Goal #4: Federal, state and local decision makers have the awareness, knowledge and skills to develop and implement effective hurricane preparedness and mitigation policies and practices.

Supporting Objectives

- Develop training and outreach materials to ensure Federal, state and local emergency managers have the knowledge and skills needed to address hurricane hazards.
- Work with existing networks of training professionals to provide access and delivery of information, tools and training to the emergency management community.

TRAINING, EDUCATION & OUTREACH (Continued)

Goal #5: Create knowledge and awareness within society to ensure responsible decision-making to undertake actions that lessen the impacts of hazards associated with tropical systems.

Supporting Objectives

- Develop and deliver an enhanced outreach program to ensure an informed and prepared public.
- Enhance education and training delivery mechanisms through partnerships and development of new outreach methods and portals.
- Evaluate the potential for establishing partnerships with other organizations to increase the effectiveness of the enhanced training and outreach program.

Appendix E

State Goals, Objectives and Priorities for the National Hurricane Mitigation and Preparedness Program

State Goals, Objectives and Priorities for the National Hurricane Mitigation and Preparedness Program

Goal 1. Coordinate and integrate Federal, state and local efforts in addressing hurricane preparedness and mitigation issues.

Objective 1.1 Create national legislation, similar to the Earthquake Hazards Reduction Act (Public Law 95-124), codifying the activities under the NHMPP as well as establishing participating agencies and eligible states.

Objective 1.2 Expand the NHMPP to include hurricane vulnerable inland states such as (but not limited to) Pennsylvania, Tennessee, Kentucky, West Virginia and Arkansas.

Objective 1.3 Encourage all participating states to internally direct their annual NHMPP funding allocation to state specific hurricane initiatives and work plans. This will ensure that state hurricane preparedness activities are fully supported by the Federal funds provided for that purpose.

Objective 1.4 Establish an annual dedicated, funding source for the continued refinement and maintenance of the HURREVAC Program.

Objective 1.5 Establish an annual, dedicated, funding source for the conduct of comprehensive post-storm meteorological, operational and programmatic assessments for all landfalling cyclones including extra-tropical storms and Nor'easters.

Objective 1.6 Incorporate new Federal agencies into the NHMPP to further broaden the scope and activities within the Program including:

- The US Geological Survey (USGS) [since they have river gauges and other useful capabilities relative to inland and coastal flooding];
- The US Navy [they have a close hurricane based relationship with NOAA/NWS/NHC and created the impetus for the five-day forecast];
- The US Coast Guard (USCG) [to coordinate bridge and marina issues];
- The Federal Imagery and Mapping Agency (FIMA) [if they'll play, for post storm damage assessment imagery and mapping capabilities];
- The National Science Foundation (NSF) [so that the Program can gain some influence over the type of hurricane research being conducted at academic institutions]; and
- Other Federal programs such as Coastal Zone Management (CZM), Dam Safety and National Flood Insurance Program (NFIP).

Objective 1.7 Establish and maintain a server and separate website that makes all NHMPP information, products and digital data readily available to any interested party.

Objective 1.8 Coordinate the research efforts of academic institutions and Federal agencies relative to hurricane related hazards; meteorology; operational plans and procedures; and mitigation techniques. This includes the convening of a hurricane research technical advisory board to review research efforts and products, as well as provide objective assessments of technical, or specialized methodologies and processes.

Objective 1.9 Establish at least one dedicated, full-time NHMPP Manager at FEMA Headquarters and in each FEMA region to coordinate Program activities.

Objective 1.10 Convene an annual meeting of all participating Federal agency representatives, state program managers and members from other organizations involved in the NHMPP to discuss Program specific issues and requirements.

Objective 1.11 Refine and improve the operations of the Hurricane Liaison Team (HLT) by:

1.11.1 Establishing a permanent, full-time management position at the National Hurricane Center (NHC);

1.11.2 Developing the capability to simultaneously contact multiple state and local EOCs to broadcast the NHC specialist's forecast; and

1.11.3 Conducting mandatory annual training for all team members.

Objective 1.12 Refine and improve the operations of the Evacuation Liaison Team (ELT) by:

1.12.1 Establishing a specialized team for each FEMA region participating in the NHMPP;

1.12.2 Providing knowledgeable representatives from local Federal Highway Administration (FHwA) offices to state EOCs as technical advisors and ELT liaisons; and

1.12.3 Conducting mandatory annual training for all team members at the regional and state level.

Objective 1.13 Consolidate emergency management related research needs and issues with the meteorological requirements contained in the National Hurricane Operational Plan (NHOP). The NHOP should become the primary criteria for assessing the validity for hurricane-related research proposals and grant awards.

Goal 2. Improve operational capabilities at the regional, state and local level to respond to hurricanes and prepare for their consequences.

Objective 2.1 Standardize and apply in all hurricane-prone states the graphical Hurricane Local Statement (HLS) issued by local National Weather Service (NWS) offices during specific hurricane threats. The graphical HLS can also be applied to extra-tropical storms and Nor'easters.

Objective 2.2 Deploy in states participating in the NHMPP an integrated Intelligent Transportation System (ITS) architecture specifically designed to manage hurricane evacuations. This includes the emplacement of such measures as:

- Real-time traffic sensors on strategic evacuation roadway segments;

- Stationary and mobile variable message signs;
- Highway advisory radio;
- Portable short range broadcast radios
- Incident management teams;
- 511 systems;
- Remotely operated cameras along critical evacuation routes;
- Integrated Traffic Management Centers (TMCs), directly linked to, or co-located with regional, state and local emergency operations centers
- Fiber-optic and other redundant communications means along major evacuation roadways.

Objective 2.3 Extend coverage of the Evacuation Traffic Information System (ETIS) to all states participating in the NHMPP, as well continue to refine and improve the program to include more evacuation traffic management capabilities.

Objective 2.4 Augment professional training for emergency management regarding hurricane preparedness and mitigation issues.

2.4.1 Update the current hurricane-related courses developed at the Emergency Management Institute (EMI): Introduction to Hurricane Preparedness (L324), and Hurricane Planning (G360) and;

2.4.2 Create additional courses in hurricane mitigation measures; decision making for the media and elected officials; and evacuation decision making, planning and management.

Objective 2.5 Develop a means to effectively communicate traffic, shelter and situation specific information directly to vehicles already on evacuation routes during a cyclone event. A more robust national ITS will be instrumental in this effort, but new technologies and methods should be investigated and exploited.

Objective 2.6 Build a strong working relationship with the hotel/motel industry to improve evacuation procedures nationwide. Because a large proportion of evacuees seek refuge in hotels and motels, better communication with the industry throughout the country will provide emergency management an effective tool to increase public safety during evacuations.

Objective 2.7 Study and develop standard guidelines and procedures for terminating evacuations, especially under exigent or emergency circumstances.

Objective 2.8 Perform an in-depth analysis of the legal implications, suitable structures, best practices and other aspects of refuges of last resort (ROLR). Develop standard guidelines and procedures for the opening and operation of ROLRs.

Objective 2.9 Study and develop standard guidelines and procedures for post-storm re-entry including legal issues, best practices and planning process.

Objective 2.10 Conduct studies determining the characteristics and impact of hurricane wind conditions on tall buildings, different types of vehicles, and nontypical structures such as parking garages, bridge overpasses and other potential refuges from wind.

Objective 2.11 Study and develop standard guidelines and procedures for special needs populations (PSNs) including the operation of special needs shelters, working with the home health care industry and detailing best practices for managing the evacuation or support of medical facilities pre and post landfall.

Objective 2.12 Conduct a national or regional hurricane response exercise each year which involves the NHC and HLT; the ELTs; FEMA Regional Operations Centers (ROC); as well as select or all state and local emergency management offices. These exercises should rehearse pre and post landfall procedures such as evacuations, re-entry, decision making and other aspects of hurricane preparedness and response.

Objective 2.13 Develop standardized technical assistance and training materials targeted to the business community regarding continuity of operations (COOP) and other preparedness measures so that the economic impacts of hurricanes are minimized.

Objective 2.14 Develop and conduct training targeted to the broadcast media and local elected officials detailing the evacuation decision making process and other emergency management activities during hurricane events.

Objective 2.15 Conduct nationwide research regarding the behavioral characteristics of tourists and visitors during hurricane evacuations.

Objective 2.16 Study the behavioral impacts of reverse lane operations to determine if such measures will cause people to delay evacuating, or predispose them to use those routes rather than other, less obvious routes to the same destinations. The behavioral surveys should ascertain the evacuees' expectations of traffic conditions, travel speeds and perceptions of safety on these routes. This behavioral data will be instrumental in determining if reverse lane operations are a truly effective means of increasing evacuation capacity.

Goal 3. Improve national capabilities regarding hazard identification and risk assessments for tropical and other cyclones.

Objective 3.1 Develop a nationwide integrated riverine and coastal flood monitoring system that allows emergency management to more effectively utilize Quantitative Precipitation Forecasts (QPFs), as well as other flood and rainfall data in preparing populations, property and infrastructure for actual hurricane events.

Objective 3.2 Establish a methodology for using existing National Flood Insurance Program (NFIP) data to develop better operational responses to hurricane induced flooding threats.

Objective 3.3 Develop a coupled wave model with the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model that will predict cyclone-induced wave heights, as well as lateral and inland extents. This data will improve damage assessment and other pre and post hurricane activities implemented by emergency management officials.

Objective 3.4 Develop historical and probability based SLOSH data to assist in land use, hazard mitigation and planning related activities.

Objective 3.5 Augment the number and capabilities of the current network of offshore buoys to provide improved advance warning of approaching cyclones, as well as provide better data for post storm assessments.

Objective 3.6 Conduct Light Detection and Ranging (LIDAR) surveys of near shore bathymetry and terrain along the entire Atlantic, Gulf and Pacific Island shorelines. This data in conjunction with LIDAR surveys of inland flood areas as part of National Flood Insurance Map Modernization Program will dramatically improve the accuracy of SLOSH models as well as surge and riverine inundation mapping.

Objective 3.7 Develop hurricane related Hazard Identification and Risk Assessment (HIRA) techniques and methodologies which relate specifically to island issues and concerns.

Objective 3.8 Institute and maintain standards which regulate the conduct of Comprehensive Hurricane Preparedness Studies (CHPS) and Post Storm Assessments prepared under the National Hurricane Mitigation and Preparedness Program (NHMPP).

Objective 3.9 Conduct an objective technical assessment and comparison of all storm tide prediction models by studying the assumptions, methodologies and technical aspects of each and also comparing the results against values observed in actual storm surge events.

Goal 4. Reduce this country’s reliance on evacuation as the primary hurricane protective action by promoting mitigation measures that protect lives and property.

Objective 4.1 Prepare standard guidelines and procedures which address the application of land use planning and growth management techniques to limit the impacts of development on evacuations and property exposure.

Objective 4.2 Develop nationwide policies and procedures, such as incentives for shuttering and “safe rooms” that encourage in-home sheltering for households not located in surge vulnerable areas, or residing in mobile homes.

Objective 4.3 Promote the application and rigorous enforcement of a minimum standard building code in coastal communities and in all areas potentially subject to hurricane force winds or greater.

Objective 4.4 Advocate that all Federal, state and local government regulations require newly constructed, non-leased government buildings in hurricane prone areas to comply with a more rigorous building code (using the prescriptive standards in ARC4496) so that those structures, when possible, can be used as shelters by local populations. Reinforced government facilities will also further continuity of government (COG), COOP and the provision of services in post storm circumstances.

Objective 4.5 Advocate that all Federal, state and local government regulations require community centers or other common structures in new mobile home parks to be constructed to the same standards as above in Objective 4.4. This will provide readily available shelter resources to residents in those communities.

Objective 4.6 Promote the use of Federal hazard mitigation (HMGP) funds for the retrofitting of schools and other public buildings, where possible, so that those facilities can serve as local shelters, even in hurricane force winds. Pre-disaster mitigation plans from states and communities participating in NHMPP should be required to also include provisions for the structural surveying and retrofit of public buildings for sheltering purposes.

Objective 4.7 In concert with the American Red Cross (ARC) and other volunteer organizations active in disasters (VOADs), ensure that all existing and future policies and procedures regarding shelter selection, operation or facility exemptions are consistently applied and complied with. This will reduce the likelihood that viable shelter facilities are not used during hurricane events due to local misinterpretation of national shelter policies and procedures.

Goal 5. Increase public awareness of hurricane preparedness and mitigation issues by developing a widespread, coordinated and pervasive information campaign with a consistent message and using all available communication resources.

Objective 5.1 Coordinate the activities of all Federal, state and local agencies to ensure that National Hurricane Preparedness Week is an annual occurrence under a Presidential proclamation, and that it is supported by a widely orchestrated public information campaign.

Objective 5.2 Develop public information materials and a nationwide campaign extolling the virtues of:

- Sheltering in place for residents not in surge zones or mobile homes;
- Evacuating the shortest distance possible; and
- Leaving as soon as possible to reduce the likelihood of encountering congestion if the intended destination is far away.

Objective 5.3 Develop public information materials and a nationwide campaign emphasizing the potentially lethal consequences of attempting to drive on flooded roadways and through inundated areas.

Objective 5.4 In concert with the movie entertainment industry, produce a series of movie trailers emphasizing important aspects of hurricane evacuation, family preparedness, the dangers of inland flooding and other salient issues. Work with theater owners and other film industry organizations to ensure that the trailers are shown before every movie in all participating states before and during hurricane season.

Objective 5.5 Develop standardized, but region specific classroom materials and lesson plans for use in primary and secondary schools, to educate children and young adults of hurricane hazards, information resources and family preparedness. Associated with this effort is obtaining certification from the appropriate educational agencies so that the classes are ready to be included as part of the official school curriculum.

Objective 5.6 Using professional media experts, develop a series or a national resource of hurricane preparedness and mitigation public information messages for radio and TV.

Objective 5.7 Work with professional news organizations and media outlets to develop consistent procedures and messages for use during hurricane related broadcasts. This effort will reduce the likelihood that actions and messages by the broadcast media during hurricane events will inadvertently conflict with advisories and instructions from local officials.